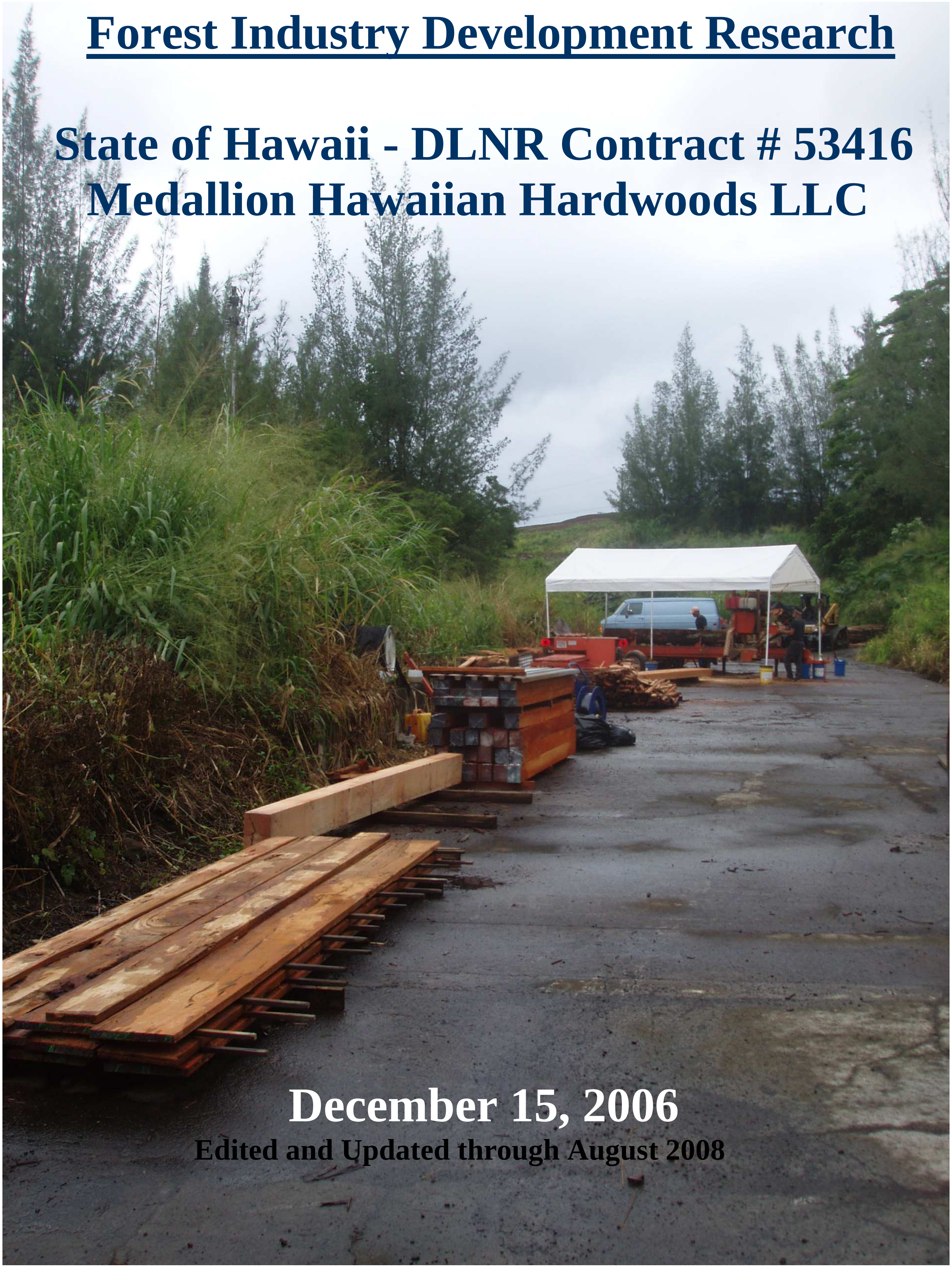
Forest Industry Development Research

State of Hawaii - DLNR Contract # 53416
Medallion Hawaiian Hardwoods LLC



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EXECUTIVE SUMMARY

The primary goal of this project is to attract investor interest in the development of higher value wood products from non-native hardwood species grown in Hawaii. This study represents 3 parts of an overall 4-part assessment of the potential for an expanded forest products industry in Hawaii. Part 1 was entitled Hawaii Hardwood Market Study and it focused on the demand side of the hardwood market in Hawaii itself. The executive summary of that report is attached as Appendix A. The full report can be accessed on the web at:

http://www.hawaii.gov/dlnr/dofaw/pubs/Hawaii%20Hardwood%20Market%20Study.pdf

The data compiled during this project provides harvest, yield and marketing information designed to assist potential investors in developing business plans that would focus on the utilization of the target species in Hawaii and abroad. The study addressed three principal project objectives each with corresponding summary of findings included:

Inventory: Summarize current availability of non-native timber resources on both public and private lands in Hawaii for four non-native timber species for which there is a current supply on Hawaii island.

1. *Eucalyptus saligna/grandis*
2. *Eucalyptus robusta*
3. *Toona ciliata* (Toon or Australian red cedar)
4. *Fraxinus uhdei* (tropical ash)

There are currently 48,340 acres of non-native timber that fit the inventory criteria for this project. Hawaii Island is home to the bulk of the timber basket with just over 41,800 acres or approximately 88% of the standing harvestable timber. Maui and Kauai combine for twelve percent with just over three thousand acres each. Further analysis shows that Maui carries a significant percentage of mixed pines and that Kauai possesses an increasing supply of *E. Deglupta.*

Harvesting , Processing and Marketing: Timber harvesting, test processing and marketing of trial solid wood products for target species were accomplished in the following quantities.

Species	Diameter Groups	Trees	Sites	Total	%	Bd Ft.
E. Saligna	5	6	3	90	56	14,000
E. Robusta	5	5	2	50	31	7,750
Toon	3	3	2	18	11	2,750
Tropical Ash	2	2	1	4	2	500
Total				162	100	25,000

There are very few operations in Hawaii that can dry and finish significant quantities of wood products. With the exception of Brauner Wood Works on Hawaii Island, most operators are focused on Koa and the processing of Koa is essentially in balance with the available and harvestable resource.

It was, therefore, very difficult to process the target volumes of wood into finished products within the time constraints of this project grant.

Eucalyptus saligna/grandis (Sydney Blue Gum)
Gross yields into green lumber form were in the range of 1.06 to 1.10 board feet of lumber to 1 board foot of log scale, International ¼ inch rule. A fall down or trim loss factor including losses due to stress related defects in the range of 10% to 15% from log to dry lumber would appear to be appropriate.

At the time of the publication of this report products had been moved to market as follows:

- Green lumber and timbers
- Flooring
- Laminated posts and beams
- Trailer decking (low boys)
- Sliced Veneer

An extensive volume of Saligna was sold in green lumber form to a local resident for construction of a utility building. Some lumber was processed into experimental glu-lam posts and beams by the University of Hawaii Manoa. A significant volume has been processed into flooring but the final sales results were not available at the time of publishing this report. Approximately 3,720 board feet of logs (International Scale) was processed into sliced veneer with a gross yield of about 108,000 square feet. This product proved to be difficult to sell due to a weak veneer market and extensive alternative species competition.

Eucalyptus robusta
The overall yield of lumber to log was 1.09 lumber tally per board foot of log scale. Some product was sold in green form to the local builder and some was being processed into flooring at the time of the completion of this report. The species generally exhibits a superior reddish brown color and character. The conversion of 3,000 bf to flooring yielded 1,512 lineal feet of untrimmed 2-1/4" and 4,605 lineal feet of untrimmed 3-1/4" product. The input lumber was predominantly from 9" wide boards. The net yield is expected to experience an additional fall down of about 20%. Additional trials displayed similar yields. E. robusta appears to have good potential as decking as well as for flooring, mouldings and casements.

Toona ciliata - (Toon or Australian red cedar)
The FIDR market focus on Toon has been toward millwork products. This species is a bit softer than the other species tested and it is softer than African Mahogany which is in currently strong favor for custom window and door construction in Hawaii. The color of the Toon is otherwise comparable with the African Mahogany. Sawmill yield was 1.18 in green lumber form.

Fraxinus uhdei (tropical ash)
Tropical Ash was processed in total to finished and sold products via Brauner. The result was an average sales realization of $3.38. A total log volume of 1690 board feet resulted in a yield of

approximately 2,300 board feet of lumber and a final sale of 1,780 square feet of product. The product was readily sold and there appears to be a good demand for this species in upper grade products.

Structural Properties of Tested Species:
Each of the species tested in this study were also evaluated for their structural strengths and densities. Wood samples were processed in Hawaii and then shipped to the Forest Products Laboratory at Richmond, CA. John Shelly PhD oversaw the testing of the species and prepared the technical summary that appears herein. The key findings were that *E. Saligna, E. robusta Toona, ciliata, and Fraxinus uhdei* all displayed good structural properties and were higher than previously published data in some cases. *E. grandis* came from juvenile (11 year old) plantation stock and did not display comparable strengths to the more mature Robusta and Saligna.

Design: Develop a conceptual timber processing facility layout that could competitively deliver the test products in the Hawaiian marketplace.

The biggest challenge in mill design is to achieve the proper balance of capacity and throughput to market and available resource. Sawmills can be designed for small log conversion or for larger log conversion. It is difficult to design a mill that can do both. Mills that are designed for small log conversion require extremely high numbers of logs in throughput to achieve acceptable economic returns on investment. The products of small diameter timber tend to be in the lower range and are basically commodity products. Larger logs yield higher grade products and the number of logs processed can be smaller on a piece count basis.
The focus of this study has been upon medium to large logs and upon capturing or recovering higher grade products. Logs below 14” in small end diameter tend to fall into the high conversion volume category. The smaller diameter logs lend themselves better to small log sawmills with high piece count throughput or rotary veneer or pulp chip markets. Larger and more mature hardwood logs tend to yield more color and character and tend to yield much higher value products. The focus of the design portion of this study has been on the larger diameter resource.

It has been difficult, historically, for processors to acquire enough resource to justify the capital expenditure that is required for a competitive large log sawmill in Hawaii. This study recommends a medium range mill design that can process 2 million to 10 million board feet of lumber production per year. Functioning in this narrow range requires a careful balance of processing machinery selection to achieve adequate throughput with limited capital investment. Other opportunities for processing smaller diameter wood into rotary veneer and pulp chips were already under design at the time of this study. An example of a medium range and lower capital mill could include a vertical band headrig, a thin kerf resaw, an edger and a two saw trimmer. Brewco machinery is used as an example of these types of machinery in this study.

II. INTRODUCTION AND METHODS

The primary goal of this project was to attract investor interest in the development of higher value wood products from non-native hardwood species grown in Hawaii. Project objectives included a review of the standing and harvestable timber, the processing and test marketing of 25,000 board feet of lumber and an overview design of a facility that could competitively process the target non-native species into the marketplace. In addition to the lumber volumes, some 3,555 board feet of logs were processed into sliced veneer which was not originally contemplated for the study.

Medallion Hawaiian Hardwoods LLC (MHH) was selected by Department of Land and Natural Resources (DLNR) of the State of Hawaii to conduct this research project. MHH, in turn, subcontracted the inventory work to Forest Solutions Inc. Harvesting, processing and marketing was subcontracted to Hawaii Island Hardwoods LLC (HIH). Some analytical work was subcontracted to JQuinn Company and the balance was done within MHH. The contract manager for Division of Forestry and Wildlife (DOFAW) was Michael Constantinides. Roger Imoto and Bob Otomo coordinated the DOFAW work on Hawaii Island.

The inventory assessment was focused primarily upon those areas that were considered to contain harvestable timber in contiguous areas large enough (50 acres or more) to justify future economic interest. The assessment focused on development of summaries of the current status of non-native timber resources on the islands of Hawaii, Maui and Kauai. Koa, Ohia and Sandalwood were not assessed in this study.

The budget designated for the inventory assessment was limited – determination of currently standing volumes for every landowner, species and age class was beyond the scope of this project. Some of the numbers presented are more accurate than others as the data were obtained from multiple sources. Data is provided for areas where information was available or landowners had a working knowledge of their forest.

Stephen E. S. Smith from Hawaii Forestry Management Consultants conducted the inventory update for Kauai. Scott Meidell at Haleakala Ranch did the review for Maui. Forest Solutions, Inc. reviewed the inventories on the Hawaii Island and coordinated the summation of all three islands.

Sawmilling was accomplished on Wood Mizer horizontal band-mills. These mills can be quite accurate but there is also a risk of “snaking” when saw blades dull, the blade is pushed too fast, or there are significant variations in density and hardness within a log. The tendency in Hawaii is to saw for heavier thicknesses to allow for variations and shrinkage.

III. RESULTS AND FINDINGS

A. Inventory

There are currently 48,340 acres of non-native timber that fit the criteria for this project. Hawaii Island is home to the bulk of the timber basket with just over 41,800 acres or approximately 88% of the standing harvestable timber. Maui and Kauai combine for twelve percent with just over three thousand acres each. Further analysis shows that Maui carries a significant percentage of mixed pines and that Kauai possesses an increasing supply of *Eucalyptus deglupta*. Larger scale processing becomes less likely on Maui and Kauai due to the limited volumes of standing timber.

Nineteen species or species groups were tracked in the study. Table A-1 provides a summary of key statistical indicators for the larger blocks from the three-island inventory analysis. Appendices B-1 and B-2 provide further inventory detail by island, landowner and species. Appendix B-2 summarizes the estimated harvest volumes from those acres assuming a 10 year rotation. Appendices B-3 and B-4 provide further inventory detail for Maui and Kauai.

Table A-1
Principal Ownerships and Inventories

Ownership	Acreage	Estimated annual harvest – 10 year rotation (ft^3)	Predominant Species
Hancock and Pinnacle Plantations	20,909	11,015,000	*E. grandis*
State of Hawaii – Hamakua	3,894	2,755,682	*E. robusta*
State of Hawaii – Waiakea	11,254	1,968,969	*E. saligna*
Kamehameha Schools – Honaunau	1,516	133,607	*E.saligna., Toon, Ash*
Mauna Kea Ranch – Hamakua	400	210,000	*E. globulus*
Total	37,973	16,083,258	

There appears to be a sufficient inventory of timber to create a substantial "industry" in Hawaii. The major issue comes from the diversity of ownerships and the difficulties for processors to obtain sufficient long term commitments to justify the required capital investments in processing. Plantation timber represents over half of the standing inventory and is dominated by the eucalypts followed by Tropical Ash and Toon. Approximately 13,000,000 cubic feet per year could be harvested from the combined ownerships that would be suitable for chip or rotary veneer production. Approximately 3,000,000 cubic feet per year could be harvested from the combined ownerships that would be suitable for lumber production.

B. Harvesting, processing and marketing

Harvesting, processing and lumber marketing trials were conducted on the four primary species - *E.saligna, E. robusta, Fraxinus uhdei* (tropical ash) and *Toona ciliata* (Australian red cedar). Some *E. saligna* was also processed into sliced veneer. Additionally, the *E. saligna* was processed from three sites each representing a different age class or variety, including a former C. Brewer plantation above Hilo, mature timber from DOFAW' s Hamakua Forest Reserve and young plantation wood from the Hamakua Coast Hancock plantation.

1. <u>Eucalyptus Saligna/Grandis</u>

Approximately 14,000 board feet of *E. Saligna* were processed for this project. Eucalyptus grows extensively on Hawaii Island and to a lesser extent on Maui and Kauai. The largest inventory of *E. saligna* is on State of Hawaii lands and in particular on the Hamakua coast. Other landowners have also planted and grown significant stands of this species. Kamehameha Schools has a significant *E. saligna* resource at their Honaunau forest. C. Brewer Company planted considerable acreages in various areas on Hawaii Island. The C. Brewer tracts have subsequently been sold to others. One such tract is owned by Kent Nelson of Sahalla Agricultural Properties (SAP) near Hilo. Prudential Timber (now Hancock) planted some 30,000 acres of former sugar cane lands between 1996 and 2002 with *E. grandis*. The largest tract of this plantation is on the Hamakua coast. Timber has been utilized from Sahalla and from the DOFAW Hoea tract on the Hamakua Coast for the manufacturing trials. A very small quantity was also processed from the Hancock plantation.

1.1 <u>Plantation Saligna</u>

Field trials began in late 2005 at SAP above Hilo, which contains plantation saligna and robusta. Kent Nelson and Paul Taylor of Taylor Enterprises Inc. (TEI) were both interested in trying to develop markets from this timber. TEI has a Wood-Mizer LT 40 portable sawmill, a Caterpillar Skid Steer and several other pieces of machinery. Three trees selected for trial processing had butt diameters of 18", 20" and 21" (Appendix B, Table 2-1). The trees were felled and then bucked into 10 foot segments. Each tree yielded about 10 log segments. The net yield was as follows:

Logs:	3,200 bf (International Scale)
Green Lumber:	3,887 bf
Yield ratio:	1.21

Log segments

Splitting segment 0101
Paul Taylor of TEI

Sawn lumber
Timber stand in background

The rough green lumber was held in air dry form at the SAP site for three months. Air-drying was not proceeding well at that elevation (2,000 ft) and in the wet conditions. All lumber was moved to

Brauner Mill Works in Hilo for further air drying and eventually for kiln drying and surfacing. The net results of the yield from this trial are summarized in Appendix C-2. A small shrinkage trial was conducted revealing 4.17% shrinkage on sap wood and 2.42% shrinkage on heart wood. The samples were air dried over a period of nearly one year and they achieved a moisture content of 12%.

1.2 Hamakua Coast Mature Saligna

In April of 2006, the Division of Forestry and Wildlife (DOFAW) felled a number of sizeable Eucalyptus Saligna trees in a timber falling exercise. A similar exercise had been conducted two years previously in an adjacent area. Both newly felled timber and two year old downed timber were utilized during the processing trials. This timber was made available to MHH for the purposes of this study.

Hoea area

50" diameter on the stump.

Paul Taylor and TEI were commissioned to do the processing. Jacobson Trucking and Logging was contracted to do the skidding and loading of logs. Double D Services was contracted for hauling and HIH was contracted to provide a site for log storage and sawmilling. This site is on property associated with the former Pepe'ekeo Sugar Company and its' surviving power plant that has been known as the North Hilo Power Company. Pacific Rim Energy Partners (PREP) is the current owner of the power plant and the 26 acre site is owned by Continental Pacific Company. Skidding and loading was conducted using a John Deere rubber tired skidder and a Caterpillar 977 front end loader. Initial deliveries utilized David Jacobson's 10 ton truck. This proved to be awkward and potentially dangerous. Subsequent shipments utilized Double D Services dumping containers.

First deliveries

Loaded dumping container – D&D

Dumping at the mill site.

Noticeable splitting

1.2.1 Sliced *E. saligna* veneer - Hoea

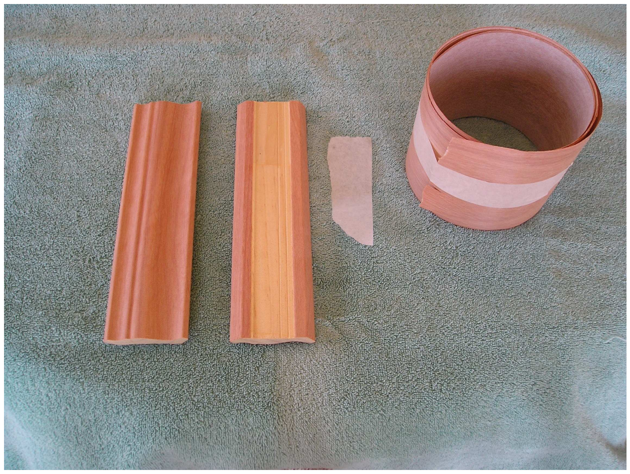
One container of high grade veneer logs from the Hoea site was shipped to M. Bohlke Veneers in Fairfield, Ohio for slicing. Most logs were pre-bucked by the DOFAW trainees and the most prevalent length was 20'-6". There are good and bad features to 20' logs. The good is that it made for a perfect fit in the dumping containers. The bad is that the larger logs are extremely heavy and the knot structure does not always fall in 10' and 20' increments. Shipment of logs to Ohio could only be done in 20' and 40' containers. The 25' boxes are not allowed on the railroad in that area. The net inside length for a 20' container is about 19'. Therefore, the veneer logs had to be cut back to 18-6".

"H" Clips were driven into the logs to retard splitting. Anchor Seal end wax was applied on both ends of the logs. All higher grade logs were also covered with shade cloth. Seven logs made "the grade" for the veneer trial. The logs left Pepe'ekeo in the second week of July. They were received in Ohio in early August and sliced in mid-August. During the trip the logs went by ship from Hilo to Long Beach, CA and by rail to Ohio. During the transit the mainland was experiencing record heat waves. Nonetheless, the condition of the logs was virtually identical in Ohio as it was when it left Hawaii.

Loaded container at Pepe'ekeo

Container at M.Bohlke veneer - Ohio

Initial market reaction to the E. Saligna veneer has been cool. The veneer is stable and attractive and the product behaves well in over-wrapping on mouldings. The veneer, however, exhibits a rather neutral coloration with a pinkish to "salmonish" hue. The wood does not display significant character or figure. An additional trial was made on wrapping the veneer onto a pine base moulding. This was done at Contact Lumber in Prineville, Oregon.



Finger jointed Architectural Moulding with E. Saligna Face

The veneer strips were finger jointed into a roll. The roll of veneer was then backed with a fleece. The fleece-backed veneer was then over-wrapped onto a finger jointed pine core. The photo above shows the face of the moulding, the back of the moulding, a sample of the fleece (a polyester cloth) and a small roll of fleece-backed veneer. Individual log yields and shipping and processing analyses are presented in Appendix B, Tables 3 and 4.
The overall yield result was:

Logs:	3,720 bf
Veneer:	108,238 sf
Cost:	$17,548
Unit cost:	$0.16 / sf random width

1.2.2 Sawn Saligna Lumber - Hoea

A total of 57,740 board feet of logs were removed from the Hoea stand on the Hamakua coast. Approximately 14,000 board feet were tracked and analyzed for this study, while the remaining wood was purchased by Hawaii Island Hardwoods LLC. All logs were numbered and the identity was painted on the ends of the logs. Log scaling was conducted by DOFAW staff. For transportation efficiency, all logs were loaded and hauled within the same short time frame. Due to limitations in the manufacturing capacity of a Wood Mizer LT 40 portable saw mill, an imbalance of inventory versus production resulted, causing a significant degree of degradation in some of the logs at the exposed low-elevation landing.

Anchor Seal end wax was applied to all log ends at the mill site. Some logs received “H” clips driven across end splits. The logs that had been left in the forest for two years did not display a high degree of splitting while on the forest floor. These same logs, did, however, begin to split after skidding, hauling and unloading at the mill site. Some of this subsequent splitting could have resulted from the handling and some could be the result of a more open exposure to sunlight and the lack of shade that the surrounding forest had afforded in the past. Shade cloth has been utilized on a large degree of the mill inventory. The shade cloth tends to reduce rapid moisture loss from direct and intense sunlight and airflow. Ideally, logs should be processed into a green product form as soon as possible - preferably within one week. Some of the logs were too large in diameter to fit onto the Wood Mizer. Eventually, the largest logs were "quartered" with a chain saw. The "quartering" tended to follow the larger and longer splits. The quartering should have been done earlier because splitting tended to be reduced after the stress had been relieved.

Even though significant end-splitting occurred, the logs can be and were processed into lumber by cutting along the splits or by edging the resulting lumber into narrower widths. It is not uncommon on the eucalyptus for one split to run the entire length of the logs. This is believed to be a stress relief event that is caused by the fast growth rate of these species. Additional end-splitting appears to be more localized and does not tend to transmit much more than one or two feet into the log.

Considerable care was taken in handling the resulting sawn lumber from these logs. Sawn boards were immediately placed into storage piles with kiln sticks inserted in each row. Units of lumber were initially restrained with plastic strapping and lids were placed on the top of each exposed unit at the end of the day's production. Eucalyptus appears to display a certain degree of plasticity that allows restrained wood to assume the configuration that is desired. Some additional splitting and warping was experienced on the ends of the lumber but the bulk of the board retains solidity.

Logs in storage yard

Sawn lumber

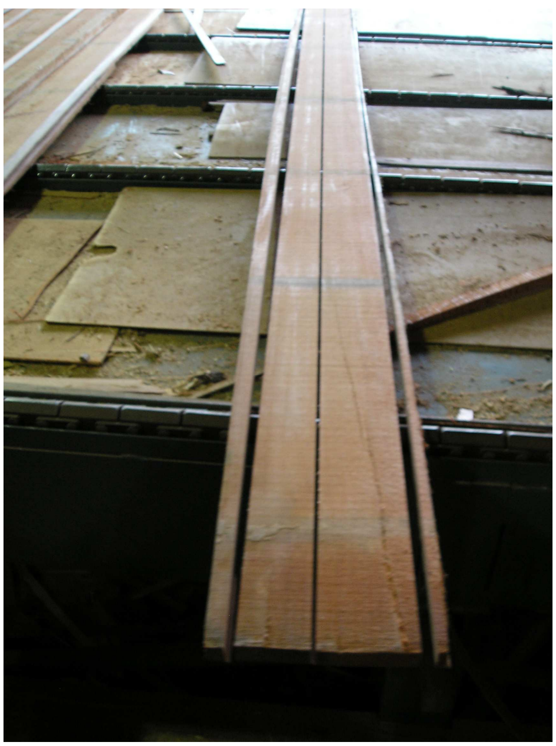
Saligna lumber was processed into flooring blanks at Bello's Millwork. The input volume was 6,800 board feet. The production of flooring blanks is summarized below.

Gross kiln dried lumber input:		9,330 bf
Moulded flooring pattern	2-1/4"	9,848 lf
		2,052 bf
Moulded flooring pattern	3-1/4"	13,894 lf
		4,052 bf
Net untrimmed flooring		6,104 bf
Yield		65.4%
Trim loss		22.8%
Final yield of trimmed flooring		47%

Unfinished flooring in process displays a mixture of clear and the occasional knot. The following photos display E. saligna in process at Bello's Millwork in Wahiawa.

Ripped board exiting Mereern Johnson Dip Chain gang saw

Ripped board exiting Mereern Johnson gang



Ripped board yielding one 2-/4 and one 3-3/4

3-3/4 flooring boards

1.3 Plantation Grandis from Hancock Plantation on the Hamakua Coast

A small trial was conducted on 10 year old plantation E. grandis from the Hancock Plantation. This trial was comprised of the butt logs only from 10 trees. The butt logs were 10 feet in length and averaged approximately 12" in top diameter. Nine of the segments were sawn and tallied. The nine logs represented 55 board feet each in log scale (International -1/4") for a total of 495 board feet. Considerable splitting occurred at the time of sawing. The lumber was placed into air drying and was not taken to market. A portion of the wood was sawn to 9/4 thickness (120 board feet) and the bulk of the lumber was sawn to 4/4 thickness (350 board feet). Samples of the 9/4 will be shipped to the Forest Products Laboratory in Richmond, California for strength testing.

When comparing the trials on SAP *E. saligna* and Plantation Grandis from the Hancock Plantation, it was clear that smaller and faster grown eucalyptus is highly prone to rapid splitting. The wood from these younger and smaller trees displayed light color that was softer than the more mature wood from larger and older trees. The resulting lumber was sold to Forest Solutions Inc. Lumber yields were comparable to those from the SAP.

Hancock Plantation Logs in inventory at the processing site

The following photos display the effect of the stresses in the juvenile wood from the plantation.

Plantation grandis center cant lifting up from the sawmill bed plates

Sawn board lifting away from the parent cant

2. Eucalyptus Robusta

Eucalyptus Robusta logs were acquired from a home site near Ahualoa on the Hamakua Coast. The timber displayed similarities in size and quality to that observed on State lands in the same region. This timber became available through the logging contractor, David Jacobson of Jacobson Trucking and Logging of Kea'au, Hawaii.

The log sizes ranged from 12" to 30" in diameter. HIH acquired approximately 11,718 board feet of logs from Jacobson. Production from this timber yielded 12,742 board feet of lumber in mixed sizes. The overall recovery ratio was 1.09 board feet of lumber per board foot of log scale on the International 1/4 " rule. Detailed yield data from the *E. robusta* processing are summarized in Appendix B.

The species generally exhibits a superior reddish brown color and character. The source wood for this project was of a lighter color than usual. The conversion of 2,520 bf to flooring yielded 1,512 lineal feet of untrimmed 2-1/4" and 4,605 lineal feet of untrimmed 3-1/4" product. The input lumber was predominantly from 9" wide boards. The net yield is expected to experience an additional fall down of about 20%.

Summary results for Robusta flooring:

Rough dry lumber:		2,686 bf
Moulded flooring pattern:	(2-1/4")	1,512 lf
		315 bf
Moulded flooring pattern:	(3-1/4")	4,605 lf
		1,343 bf
Total moulded blanks		1,656 bf
Net yield		61.7%
Trim loss		22.8%
Final yield of trimmed flooring from original lumber input		48%

Additional trials on E. *robusta* (sourced from private lands and from the Boy Scout Camp at Honokaa, provided the following statistical results.

- A trial on 1x6 exterior decking:
    - 2,000 board feet input. Special cut and sorted at about 30% of log input.
    - Sawn for 16 foot lengths and air dried for one month and then kiln dried in a Nyle dehumidification kiln using adjustable cargo straps to keep the lumber in line.
    - 932 lineal feet of select deck (466 board feet). Sold at $1.95/ lineal foot
    - 1,120 board feet of narrow select.
    - Net yield = 1,586 or 76% of select input
- A trial on random width 4/4 (rough dry input).
    - 3,352 bf input.
    - Select grade (no more than two small tight knots per board) S2S = 935 ft.
    - T & G Flooring:
        - 2-1/4" = 493 ft
        - 3-1/4" = 900 ft

All trials have reinforced the observations that:

- logs should be processed into lumber as quickly as possible after timber falling,
- lumber needs to be carefully stacked with kiln sticks in precise alignment,
- restraints are important (weight on top or adjustable straps),
- lids on top of exposed air drying loads help reduce surface checking and cupping.

3. Tropical Ash

Tropical ash timber was obtained from DOFAW via a road maintenance operation along Blair Road, in the Laupahoehoe Section of Hilo Forest Reserve. This timber was relatively mature and displayed good stability in processing. It is a light colored wood but one that proves to be easily accepted in the cabinetry and paneling market segments in Hawaii. There is a definite market for this species when the tree sizes are similar to those in this trial. Butt diameters for the trees harvested for the trial ranged from 11" to 21".

Test results on Tropical Ash were:

Logs:	1,700 bf
Green lumber:	2,300 bf
Finished lumber:	1,748 sf
Average sales realization:	$3.38 per sf

Tropical ash processing costs and yield data are summarized in Appendix B.

Tree number 2 with Bob Otomo of DOFAW

Rough dry lumber at Brauner

Straight line rip saw at Brauner Millworks

Select grade boards

1. Toona ciliata (Australian Red Cedar) - Toon

Though Toona ciliata – Australian Red Cedar – is not a true cedar, it does in fact display many typical cedar features. The wood is not as hard as the eucalypts but it possesses much more stability in the green state. Toon develops a pleasant darker coloration and it is very easy to work with. There is some splitting during logging but it is far less than what was experienced with the Saligna and Robusta. There is virtually no splitting in logs larger than 18” in butt diameter even after being in storage for several months.

The original budget called for approximately 2,500 board feet of Toon to be processed during the project. The site for the most representative stand of Toon was found to be in the Waiakea forest south of Hilo. Access to this site was from “L Road.” Because D&D services could not take their dump containers directly to the felling site, an uphill skidding scenario comprising a one-mile, 300-foot rise over wet and rough ground was required. This scenario also necessitated that Jacobson Trucking and Logging employ the use of their FMC skidder.

Toon tree number one

Leaning Nepal Alder

Stump view of Toon tree number one

Loading D&D with Jacobson's FMC

The Toon was processed into heavy 8/4 and 4/4 thicknesses. The focus on the 8/4 was for 6.5 to 8.25 inch wide lumber for a trial at Bello's on door stock. Bello's Millwork is currently utilizing large quantities of African Mahogany in the construction of custom doors and windows.

African Mahogany left two pieces
Toon stock in balance of unit

Infeed of Toon to Wintersteiger veneer saw

Outfeed of sawn veneer from frame saw
balance is toon

Sawn veneer – darker piece is mahogany

It was interesting to note that the dark red color that was displayed on the butt cut of tree number one did not carry over into the sawn lumber. The moisture in the log carries the reddish tint but it dissipates when exposed to the air and light. Toon wood that has been exposed to the light for some time will again darken.

Test results on green processing were:

Logs:	3,445
Green lumber:	2,900
Yield ratio:	1.19

5. <u>Manufacturing observations</u>

Manufacturing in Hawaii is currently limited to processing on portable sawing machinery. In this project all sawing was done on a Wood Mizer portable horizontal resaw. There is also a limited capacity for kiln drying, lumber finishing and value added processing in Hawaii. Brauner Woodworks was very helpful in the processing of the plantation eucalyptus saligna and the tropical ash. Hal Brauner is very knowledgeable on most all species in Hawaii. His operation includes contracted sawmilling, a resaw, three dehumidification dry kilns, a straight line rip saw, a planer and a moulder.

Brauner carries a significant inventory and variety of species. The *E. saligna*, *E. robusta* and the Toon volumes from this project were too great to expect Brauner Woodworks to be able to handle this and their usual business volume simultaneously. Therefore, the processing of Hoea *E. saligna*, *E. robusta* and *Toona ciliata* for this study needed to be processed through other facilities, and in some cases direct sales of green and air dried lumber in the local market were required.

Brauner Woodworks operates with a heavy focus on flooring and panel products except where clear and select lumber can be recovered from the resource. Brauner can skip plane kiln dried lumber and then run it through a straight line rip saw for the selection and recovery of maximized yield and grade recovery. Clear and select grade lumber can be sorted off of the rip saw and the remaining lumber can be processed into flooring. No other operator on Hawaii Island can presently offer this combination of processing. Brauner is selling flooring and paneling from E. Robusta and E. Saligna for about $4.15 per square foot. Annual lumber processing is about 350,000 board feet and flooring and paneling sales run about 2,000 bf/wk.

HIH was able to establish a relationship with Pictures Plus and with Bello's Millwork on Oahu for kiln drying and finishing. Early shipments included un-edged flat and quarter sawn lumber. The un-edged lumber did, however, present a problem in shipping integrity and waste disposal. The sloped edge or wane on the edge of the lumber results in tapered widths along the length of the sawn lumber. This also manifests irregular lumber widths and inconsistent course widths. The net result of these features is that it is very difficult to keep a unit of lumber tightly strapped during transfer. Most millwork shops have a real problem with the disposal of edgings, shavings, chips and sawdust. Therefore, the urban processors prefer to purchase edged or four sided products.

HIH was also able to establish a relationship with Andrew Plack to supply lumber in varying sizes for the construction of a unique building near Pepe'ekeo. The net of these relationships was the need to remove the wane from all lumber production and sell four sided pieces. Koa Aina Inc. provided a portable edger to accomplish the production of the four-sided lumber.

The primary issue encountered during eucalyptus processing was the propensity for logs (all sizes) to split prior to and during processing. The splitting of logs can be heard and seen as soon as a tree hits the ground. Splitting continues when timber is brought to a processing site and is exacerbated by being exposed to sunlight. Felled timber that had been left on the forest floor for two years, nonetheless, experienced significant splitting at a lower elevation with more exposure. It is quite likely that the handling of logs with the use of skidders and trucking will also contribute to additional and accelerated splitting.

The stress results in splitting and in some warpage in eucalyptus lumber. The yield of solid lumber from the logs is not, however, dramatically affected by the splitting. This is because it is possible to cut along the split lines. Most minor splits stop within a foot or two of the end of the log. Once the log has been converted to lumber the stresses in the log appear to have been relieved and subsequent splitting is much less.

A great deal of emphasis was placed upon sawing accuracy and stabilized lumber stacking during the trials. Operators at Bello's Millwork have commented that the sawing accuracy on the *E. Saligna* was the best that they had seen from a sawmill operation in Hawaii. Initial production was stickered, strapped and lidded to restrain the lumber and to reduce weather checking and splitting during air drying and shipping. Lumber should be stored on a flat surface (paved being best) with kiln sticks being placed as nearly as possible in direct vertical alignment with each other. These measures were critically important in maximizing lumber yield. Anchor seal end wax was also applied to the ends of the sawn lumber in an attempt to further diminish the splitting effects. Over time, it became more apparent that strapping of green lumber was not necessary if the units were stacked straight and the unit separation bolsters were kept properly aligned with a row of stickers. Once properly dried, eucalyptus lumber exhibits great strength and stability after manufacturing.

It is not unreasonable to expect significant down fall on eucalyptus from tree to finished product. A fall down or trim loss factor including losses due to stress related defects in the range of 10% to 15% from log to dry lumber would appear to be appropriate.

Both the Ash and Toon appear to have better dimensional stability than the eucalypts in initial processing and are very easy to work with. Eucalyptus is a much harder and denser wood that lends itself particularly well to hardwood flooring. Similar eucalyptus species are used in furniture production in Africa and in Australia. Limited production of custom furniture has taken place in Hawaii as show in the following photo of a table made of solid sawn wood and sawn Saligna veneer.

Lumber processing at HIH at Pepe'ekeo

A unit of mixed four sided, three sided, and two sided 4/4 lumber

6. Product Applications

As previously mentioned, processed *E. saligna* was delivered to customers on Hawaii Island and on Oahu. Some 5,000 board feet of kiln dried 4/4 *E. saligna* was surfaced and trimmed by Bello and sold to Associate Professor Amy Anderson of the University of Hawaii at Manoa School of Architecture. The yield was approximately 50% from kiln dried rough un-edged lumber to finished 6" widths. A similar yield is generally experienced in the production of hardwood flooring. In addition, Mr. Plack purchased a variety of products and sizes that range from 4/4 boards to 6x10 timbers. *E. saligna* was also sold in green form in 2x12 for low-boy trailer flooring and some was sold in 6"x6" in 7 foot lengths for posts for a home foundation. These timbers were eventually reprocessed into octagonal configuration and finished with polyurethane.

6.1 University of Hawaii Manoa School of Architecture project

Professor Anderson is leading a prototypical design and development project at U.H. Manoa that is focused on the utilization of locally grown species. Using *E. saligna* lumber, this experimental project is developing Glue-Lam and laminated veneer lumber beams to be used with concurrently developed home designs that might ultimately be used in potential home construction for the State Department of Hawaii Homelands. Their project and approach incorporates privileged designs of special hardware for fastening the posts and beams together. The *E. saligna* displays good character and color and results in a very stable beam.

6.2 Andrew Plack

A large amount of the lumber produced during the project was delivered to Andrew Plack. Some of the product is being held in air drying on his property for future installation. Other products are being used in the first phase development of a storage structure that will be followed by the construction of a house. Eucalyptus will play a key role in the construction of both structures.

Initial framing of post and beam storage structure

Notched and pegged fastening

The posts for this structure are from the Sahalla stand near Hilo, HI. The framing lumber and beams are from the Hoea stand as sawn at Pepe'ekeo under the HIH contract.

"The use of Eucalyptus as a forestry product with a broad range of applications is little understood outside of their native land of Australia. Hawaii is situated in a unique position to facilitate our own production and use of this material. Furthermore, a local market is already in place but undereducated about usefulness of Eucalyptus. Eucalyptus species in our forest reserves are naturally termite and fungi resistant. Both Eucalyptus robusta and saligna are used in other countries for dimensional lumber, heavy construction, ply board, laminated beams, and many other applications. Our local experience with Eucalyptus Saligna and Robusta has been enthusiastic. The wood is stronger and harder than many other hardwoods. The wood may be completely stabilized with a long slow drying time. Some waste is expressed in checking and splitting due to structural fiber mechanics. The remaining wood product is very good. It is useful for many local applications." Andrew R. Plack

6.3 E. *saligna* and E. *robusta* Product Applications and Marketing Observations

Some saligna stands exhibit a darker reddish color than others. Numerous stands are a mixture of saligna and grandis. The tow species are difficult to distinguish from each other. A study of leaf characteristics is required. Younger stands of saligna exhibit a lighter color and a somewhat salmon like shade. The wood can be stained and it takes color modification well. Darker woods are more readily marketed for flooring, trim and mouldings while the lighter colors work better in cabinetry. E. *robusta* is readily accepted for flooring and trim and it appears that it may have good potential for exterior decking.

Mouldings for a fireplace

Experimental Robusta Deck
(Center and edge boards with deck sealer)
(Small piece of Ipe decking for comparison)

Crown Moulding, Casements and Floor Moulding at Walua Road Office Building - Kona

7. Conclusions:

The primary focus of processing the Eucalyptus has been on solid lumber products from larger and older trees. This is based upon the assumption that it is something that can be accomplished in Hawaii with lower capital expenditure equipment and the assumption that the yield from timber susceptible to splitting will be higher into solid lumber products than into veneer.

All of the Tropical Ash was sold quickly after being processed into a semi-finished form. Most of the ash wood went into paneling, while a portion was processed into flooring. The largest volume of wood processed was *E. Saligna*, with a majority used as described above. The balance of the material was processed into flooring and millwork. The target green thickness for eucalyptus was heavily influenced toward hardwood flooring with a finished thickness of 7/8". The net result is that the recovery ratio is in the range of 1.10 board feet of green lumber per 1.00 board feet of log scale on the International ¼" rule.

Toon displays great color and the highest stability during the drying process, and will be marketed in the millwork and paneling market segments. Over 1/3 of the *E. Robusta* has also gone to Mr. Plack's construction project. The net yield on *E. Robusta* is similar to that from *E. Saligna*. Both Hal Brauner of Brauner Woodworks and Eric Bello of Bello's Millwork predict net yields of flooring to be in the range of 50% of log scale.

Sales, marketing and utilization of the species studied have been hampered by the lack of infrastructure on Hawaii Island at this time. Every aspect of the wood business is more expensive in Hawaii than it is on the US mainland or in other countries due to several factors:

a. Higher fuel and energy prices.
b. Rough and unimproved forest roads.
c. Mountainous terrain.
d. Higher labor rates.
e. Higher worker compensation insurance costs.
f. Lack of infrastructure and by-product options.

Several opportunities balance against such disadvantages:

a. Rapid growth rates of timber.
b. High degree of renewability.
c. Superior appearance and structural qualities of the wood.
d. A high degree of potential customer interest and acceptance to locally grown and processed wood.
e. A current imbalance of timber inventory over processing capacity.

It is apparent that vertical integration and a complete commitment to processing from stump to final customer is far more important in Hawaii than in many other parts of the world. This comes about as a result of the currently limited scale and capitalization of logging, milling, drying and finishing. In many places there will be a wide choice of contract loggers, custom milling, custom drying and value adding businesses. While some of these exist in one form or another in Hawaii, there are not a significant number of choices and none match the potential market or the potential resource base.

Acceptance of most of the products from this project has been quite good. The timing of the study compared to the availability of processing has limited the amount of final product acceptance data that had been hoped for from the outset. The people who have been involved in the processing have all been impressed with the appearance of these species. The ultimate placement of the products into the market should confirm the theory that larger diameter and darker colored hardwoods from eucalyptus and toon will be marketable in Hawaii and abroad.

C. Structural Properties of Tested Species

1. Introduction

The growing interest in producing products from local resources for local markets has emphasized the need to not only understand the local markets but to also understand the properties and characteristics of the local resources. This is of particular interest in Hawaii were many non-native species where planted and continue to be planted for both investment and land restoration. Many of the species found to grow well in the Hawaiian Islands are derived from Australia. Some of these are commercial species that are well known in Australia with well documented growth characteristics and wood properties. Table 1 summarizes information on the properties of some Hawaiian grown woods compiled from the published literature. However, the question that needs answered is if the properties determined from trees grown in Australia reliably represent the properties of trees grown in Hawaii. Although a few studies were conducted with Hawaiian woods about 40 years ago the results were based on small sample sizes on trees growing under different conditions that are found into today's forests. The same question applies; are the values reliable today?

Table 1. ***Selected mechanical properties of a few Hawaiian-grown woods found reported in the literature.***

Common Name	Species	Ref. #	Density (g/cm^3 at 12% MC)	MOR (psi)	MOE (million psi)	Compression parallel to grain) (psi)	Shear (psi)
Rose Gum	*E. grandis*	*2, 3, 4, 6*	0.69	15,965	2.189	8,598	1,887
Swamp Mahogany	*E. robusta*	*3, 4, 6, 7, 8*	0.80	14,124	2.014	7,783	1,900
Sydney Blue Gum	*E. saligna*	*1, 2, 3, 4, 6, 7*	0.75	16,512	2.351	9,425	2,037
Toon	*Toona sp.* (also includes *Cedrela sp.*)	*1, 2, 3, 4, 5, 6*	0.47	9,277	1.204	5,326	1,378
Tropical Ash	*Fraxinus uhdei*	*4, 6*	0.58	12,128	1.606	6,672	1,697

Ref. #	List of References (Ref #) for Table 1
1	Welch, M.B. 1923. Notes on Strength of Timbers with List of Transverse Tests on Specimens in the Technological Museum. Bulletin no. 13 Sydney
2	Wallis, Norman K. 1956. Australian Timber Handbook. The Timber Development Association of Australia
3	Bootle, Keith R. 1983. Wood in Australia Types, Properties and Uses. Sydney
4	Keating, W.G. and Elanor Bolza. 1982. Characteristics, Properties, and Uses of Timbers from South East Asia, Northern Australia, and the Pacific. Vol. 1. Sydney
5	Chudnoff, Martin. 1984. Tropical Timbers of the World. USDA Agricultural Handbook 607.
6	Skolmen, Roger G. 1974. Some Woods of Hawaii… properties and uses of 16 commercial species. USDA Forest Service general Technical Report PSW-8
7	Jaakko Poyry Consulting. 1999. Market Research on Commodity Wood Products from 8 Non-Native, Hawaiian Grown Timber Species. Unpublished.
8	Skolmen, Roger G. 1963. Robusta Eucalyptus wood, its properties and uses. USDA Forest Service general Technical Report PSW-9
9	Skolmen, Roger G. 1972. Specific gravity variation in robusta eucalyptus grown in Hawaii. USDA Forest Service general Technical Report PSW-78
10	Wood Handbook: Wood as an engineering material. 1999. USDA Forest Service General Technical Report FPL-GTR-113

2. Objectives

This project was initiated to determine the wood properties of five species growing in Hawaii that are considered good candidates for local wood markets. The species selected are *Eucalyptus grandis*, *Eucalyptus robusta*, *Eucalyptus saligna*, *Toona ciliate (toon)*, and *Fraxinus uhdei (tropical ash)*. These species are thought to occur in sufficient volume to support a local market, the eucalyptus species are thought to have decent woodworking and structural use properties, and the toon and tropical ash are thought to have desirable woodworking properties.

Wood density, bending strength, and bending stiffness were selected as the three wood properties to characterize each species. Wood density was chosen because it is physical property that is very well correlated to all other wood properties and it is a well known general rule that woods of the similar density have similar properties. Of course there are exceptions, which is why other properties also need to be tested. Bending strength and bending stiffness are two mechanical properties that are derived from the standard bending test. The bending test measures a complicated interaction of compression, tension, and shear forces. This makes the bending test a good predictor of other these other mechanical properties. To complete the evaluation of these species two other properties, hardness and machinability, will be completed at a later date with the same specimens used in the bending test.

3. Methods.

Specimen Preparation – The specimen material was harvested, milled to rough test dimensions, and partially air-dried by Hawaii Island Hardwoods LLC. All of the trees selected for harvest were near Hilo, HI; the specific location is stated in Table 2. Multiple diameters and sites were sampled as described in Table 2. Each tree was milled into lumber and the specimens of each species selected for testing were chosen from the lumber produced. Only one *E. grandis* tree was selected for testing. The 24 specimens of *E. robusta* represented a sample population of 50 trees; the 24 *E. saligna* specimens represented 90 trees; the 12 *Fraxinus uhdei* (tropical ash) specimens represented 4 trees; and the 24 *Toona cilata* (Toon) specimens represented 18 trees.

Table 2. ***Selection criteria for the species and specimens selected for testing***

Species	Number of Trees Harvested	num. trees x num. diameter groups x num. sites	Location of Sites	Number of Specimens for Testing
E. grandis	1	1 x1 x 1	Hamakua Coast – Prudential Plantation	4
E. robusta	50	5 x 5 x 2	Ahualoa	24
E. saligna	90	6 x 5 x 3	Hamakua Coast – Hoea tract	24
Fraxinus uhdei	4	2 x 2 x 1	Blair Road	12
Toona ciliata	18	3 x 3 x 2	Waiakea Timber Management Area	24

The specimens chosen for testing were rough milled to lengths of 48 inches with a square cross section of 2 ½ x 2 ½ inches (Figure 1). These were slowly air dried to a moisture content of about 30% (Figure 2) and then shipped to the University of California Forest Products Laboratory in Richmond, CA for final specimen preparation and testing. The rough-milled specimens were placed in a controlled environment room and slowly dried to an equilibrium moisture content of 12%. Specimens were then milled to final dimensions of 2 x 2 x 30 inches (Figure 3).

photo by Jim Quinn

Figure 1. Rough-sawn specimens.

photo by Jim Quinn
Figure 2. Specimens in air-drying yard.

Figure 3. Specimen milled to final dimensions.

Each specimen was closely examined for defects and only clear wood specimens selected for the tests. If defects were present that would interfere with the test results than the 2 x 2 specimen was milled to the alternate size of 1 x 1 x 16 inch. Testing followed the specifications defined in ASTM Standard D 143 – 94, Standard Test Methods for Small Clear Specimens of Timber[1]. The bending tests were conducted on a Baldwin Universal Testing Machine (Figure 4).

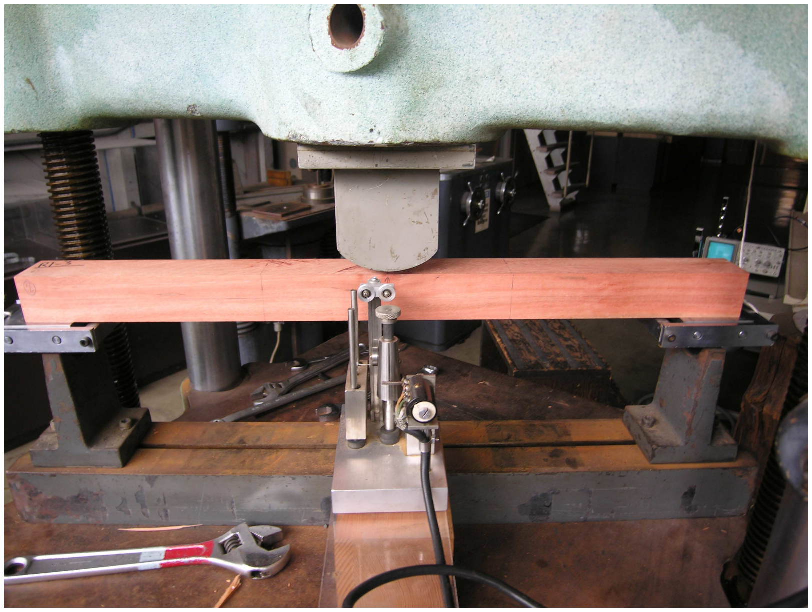


Figure 4. Test specimen placed in the bending test jig of the Baldwin Universal Testing Machine

Properties Tested – The ASTM standard methods were used to determine the following standard mechanical properties of each of the five selected species.

- Bending Strength (Modulus of Rupture or MOR)
- Bending Stiffness (Modulus of Elasticity or MOE)
- Density at 12% moisture content
- Specific Gravity on an oven-dry mass and oven-dry volume basis

The mechanical property of hardness and the physical properties of dimensional change and machinability will be determined from the same specimens at a later date.

[1] Annual Book of ASTM Standards 2006. Section Four, Construction. Volume 04.10, Wood. American Society for Testing and Materials. West Conshohocken, PA.

4. Results

The results of the bending test are presented below in Table 3.

Table 3. Summary of Wood Properties from the Bending Tests.

Species	Specific Gravity	Density at 12% test MC (g/cm^3)	MOE (psi)	MOR (psi)
E. grandis *stand. dev.*	0.39 *(0.09)*	0.419 *(.091)*	1,393,766 *(575,643)*	9,072 *(2,351)*
E. robusta *stand. dev.*	0.64 *(0.06)*	0.672 *(0.06)*	2,128,631 *(565,643)*	14,262 *(2,863)*
E. saligna *stand. dev.*	0.84 *(0.11)*	0.875 *(0.11)*	2,892,496 *(718,534)*	19,672 *(4,209)*
Fraxinus uhdei *stand. dev.*	0.55 *(0.04)*	0.586 *(0.04)*	1,388,697 *(203,254)*	12,019 *(1,959)*
Toona ciliate *stand. dev.*	0.44 *(0.04)*	0.47 *(0.05)*	1,475,921 *(226,294)*	11,210 *(1,679)*

E. grandis – The average specific gravity of 0.39 and density at 12% MC of 0.42 g/cm^3 are significantly lower than the values previously reported in the literature. The bending test values of 1.39 million psi for stiffness (MOE) and 9,072 psi for strength (MOR) are also in the range expected for wood with a specific gravity of 0.39. However these MOE and MOR values are significantly lower than previously reported, by 36% and 43% respectfully.
E. robusta – The average specific gravity of 0.64 and density at 12% MC of 0.67 g/cm^3 are significantly lower than the values previously reported in the literature. The bending test values of 2.13 million psi for stiffness (MOE) and 14,262 psi for strength (MOR) are slightly higher than the range expected for wood with a specific gravity of 0.64. These MOE and MOR values are higher than previously reported, b y 6% and 1% respectfully.
E. saligna – The average specific gravity of 0.84 and density at 12% MC of 0.87 g/cm^3 are significantly higher than the values previously reported in the literature. The bending test values of 2.89 million psi for stiffness (MOE) and 19,672 psi for strength (MOR) are also higher than the range expected for wood with a specific gravity of 0.84. These MOE and MOR values are higher than previously reported, by 23% and 19% respectfully.

Fraxinus uhdei – The average specific gravity of 0.55 and density at 12% MC of 0.59 g/cm^3 are very similar to the values previously reported in the literature. The bending test values of 1.39 million psi for stiffness (MOE) and 12,090 psi for strength (MOR) are also in the range expected for wood with a specific gravity of 0.55. However, these MOE and MOR values are lower than previously reported, by 13% and 1% respectfully.
Toona ciliate – The average specific gravity of 0.44 and density at 12% MC of 0.47 g/cm^3 are significantly lower than the values previously reported in the literature. The bending test values of 1.47 million psi for

stiffness (MOE) and 11,210 psi for strength (MOR) are higher than the range expected for wood with a specific gravity of 0.44. Also, these MOE and MOR values are significantly greater than previously reported, by 23% and 21% respectfully.

5. Conclusions

The results emphasize the importance of confirming wood properties of new resources. Although values of various properties may exist in the literature the influence of different growing conditions and genetic variation may have major effects on the properties that cannot be ignored. All of the five species tested in this project showed such variation in at least one property.

The two species that had properties most similar to previously published values were *E. robusta* and *Fraxinus uhdei*. Although the *E. robusta* was found to have a density about 22% lower than the density reported in the literature, the values for bending strength (MOR) and stiffness (MOE) were very similar to reported values. The Fraxinus uhdei showed slightly lower bending stiffness than expected but the other properties were very similar to previously reported values. These discrepancies with the previous studies cannot be adequately explained without a detailed analysis of old data that is no longer available.

The *Toona ciliate* and the *E. saligna* tested in this study performed better than previously published values. The *Toona ciliate* was only slighty greater in strength and stiffnes but the *E. saligna* was significantly denser (12% greater), stronger (19% greater), and stiffer (23% greater) than specimens previously tested.

The plantation grown *Eucalyptus grandis* tested in this project was found to be about 40% lower in strength (MOR) and stiffness (MOE) than previously reported values for the species. This result emphasizes the importance of understanding the characteristics of plantation grown trees that are often selected for specific genetic traits. For example, trees selected for fast growing fiber often have high percentages of juvenile wood that is known to have lower than expected strength properties.

As a comparison, consider Douglas-fir (*Pseudotsuga menziesii*), which is known as a benchmark species for structural uses of wood. The average MOR for Douglas-fir is 12,400 psi at 12% MC and the MOE is 1.95 million psi. The *E. robusta* sampled in this project has values in these two key properties about 10% greater than Douglas-fir values. The *E. saligna* sampled in this project is about 50% stronger and stiffer than Douglas-fir. The other three species had strength and stiffness values lower than Douglas-fir. The more than favorable comparison of *E. robusta* and *E. saligna* with Douglas-fir provide strong evidence that these two eucalyptus species will perform well in structural uses.

In summary, *E. robusta* and *E. saligna* exhibit properties that are very favorable for structural uses. The clear wood values for strength and stiffness documented in this report can be used to determine building design values that exceed the design values of Douglas-fir of a similar grade. On the basis of this project, *Fraxinus uhdei*, and *Toona cilate* could be recommended for structural uses but they would be inferior in the use to the benchmark Douglas-fir. The clear wood values documented in this report could also be used to develop design values for these species. The values documented in this report for E. grandis are based on too small of a sample size to be reliable and should not be used for design value calculations. Without further study, the plantation *E. grandis* cannot be recommended for any structural uses and care should be taken for any solid wood use of the species until more is known about it.

D. Design.

The current absence of supporting infrastructure and markets for lumber processing byproducts makes mill design more challenging in Hawaii than on the mainland. One of the greatest challenges to the establishment of a significant processing operation in Hawaii has been the lack of committed resource supply in sufficient magnitude to justify the capital expenditures for equipment such as described above. Sufficient timber exists to justify such investments in forest stands such as the State's Waiakea and Hamakua forests, the Kamehameha Schools Honaunau forest and in a variety of private ownerships. These stands all contain tree sizes that would lend themselves well to a vertical band mill and traveling carriage type of primary breakdown system. Lumber products could also be derived from the younger plantation stands when the trees achieve butt diameters in excess of 16".

All timber stands will contain a mixture of sizes of trees. This has presented yet another challenge to equipment selections. With the coming of chipping plants, bio-mass power plants and possibly rotary veneer operations, alternative markets for smaller diameter logs is no longer beyond the realm of reason. Nonetheless, it should be possible to install competitively efficient operations when timber supplies can be brought under contract to justify the capital investments.

In all sizes of eucalyptus it is important to process the logs as soon possible after logging and then to turn the log as rapidly as possible during sawing in order to equalize or neutralize the stresses. In smaller logs, which have the greatest internal stresses, a preferred approach might be to make the initial pass through a set of vertical twin band saws (often referred to as a "scragg" mill). In larger logs it is just as effective to utilize a more conventional vertical band saw with a traveling carriage and a hefty log turner. A vertical band mill also affords the sawyer with the best opportunity to visually assess the quality of the log and make the best decisions on subsequent orientation and cutting of the log.

The design of a wood processing facility needs to be properly aligned to match the available resource to the target market with an operating efficiency that can deliver the product to the market at a competitively advantageous price. The market for furniture and millwork grade lumber is dictated primarily by the landed cost of suitable products from the mainland or abroad. Select grades are going to run in the range of $3.00 to $8.00 per board foot kiln dried and surfaced. Flooring prices will be in the range of $4.00 to $7.00 per square foot with tongue and groove. Common grades with tight knots and good character can bring prices in the range of $2.00 per board foot air dried. These price ranges are based upon wholesale pricing levels as published by Hardwood Review and field input from Hawaiian market participants.

The following costs were applicable for the non-native species evaluated in this study, and represent current market conditions in Hawaii:

Item	Cost per board foot
Stumpage	\$0.20 to \$0.40
Logging and log delivery to mill	\$0.70 to \$0.90
Milling/manufacturing (see note below)	\$0.40 to \$0.60
Lumber drying	\$0.30 to \$1.00
Total	\$1.60 to \$2.90

Manufacturing costs from a sawmill would need to land in the range per board foot stated above in order to insure a profit on the total mix of products after finishing. The trials in this project resulted in manufacturing costs of approximately \$0.80 per board foot (corresponding to production rates of approximately 100 board feet per hour) due to scale inefficiencies. The trial utilized a small Wood Mizer LT 40 portable band saw with a 1" wide saw blade and a portable edger. The edger was limited to processing only 4/4 lumber due to the lack of power compared to the hardness of the wood.

There are no automated handling systems for rough lumber processing and in Hawaii at this time. This means that all lumber is being stacked manually with stickers being inserted manually to provide the air passages for proper drying. The un-stacking is also manual. A competitive mill will need to include extensive mechanization of lumber handling as well as the utilization of properly sized sawing, edging and finishing equipment. Full scale sawmills on the mainland and in other parts of the world generally utilize large vertical band saws with 30" to 40" drive wheels and saw blades that are in the range of 4" to 8" in width. These sizes of band mills require considerable infrastructure including sizeable foundations. Such designs are very capital intensive and they require large throughput production volumes. A typical competitive mainland hardwood mill will produce in excess of 10,000,000 board feet per year.

Large log band mills and rail-mounted carriages are quite typical in the industry. These types of mills also possess the necessary support equipment and experience for the tensioning and sharpening of the large saw blades. Such facilities (filing rooms) represent a need for significant volumes of wood to be processed to justify the capital expense and the staffing for proper saw maintenance.

Between the large log mills and the portable mills are a host of smaller to mid ranged equipment options. Heartwood Company produces a more powerful double cut (the saw can cut in both directions of movement) horizontal band mill. Horizontal mills do not lend themselves as well toward sawyer visibility of the opened faces of the log and they tend to be less efficient in turning the logs for the next cut. Sanborn has produced a semi-portable tilted double cut band mill that shows great potential for sawyer visualization and log handling but the field reports on feed speed and mechanical upkeep have not been positive.

There has been a proliferation of small portable circle band saws for limited scale use in recent years. This trend has come about from the desire to reduce capital costs in smaller capacity mill installations. Hawaii has been a natural fit for these types of mills. The use of small circle saw mills has some advantages but many disadvantages. The primary advantage is the ability to quarter saw for grade.

The disadvantages included slow sawing speeds, limited widths of cants or flitches, and heavy kerfs. The narrow and thin blades on Wood Mizer type mills results in reduced kerf but limits the speed of cut. They also become susceptible to inaccuracy when the blades begin to dull, when feeds speeds are too high or when logs display inconsistent hardness.

This study has focused on trying to find a path that would land in between the high capital cost and high capacity band mills and the low capital cost and low capacity portable mills. Attention was also directed toward the issue of avoiding the capital expenditures that are required for full scale filing rooms. There are processing devices that fall in between these extremes. Such equipment will not be portable but it will not require as much infrastructure and foundation support as the more conventional large mills.

Portable mills produce lumber at a rate of approximately 1,000 to 4,000 board feet per day depending upon the species and size and shape of the logs. Higher production mills will produce in excess of 50,000 board feet per day. Based upon a net of 200 work days per year, these two contrasting configurations represent 200,000 board feet per year and 10,000,000 board feet per year respectively. When considered together, currently existing timber inventories on Hawaii Island and local wood marketing potential appear to favor mill capacities that fall in the range of 2,000,000 to 5,000,000 board feet per year.

1. <u>Sawmill Design</u>

Brewco Inc. (http://www.brewcoinc.com) is one supplier of equipment that conforms to this mid range of operations. Brewco band mills have 2" wide blades and can be used in either a vertical or horizontal configuration. Feed speeds on the 2" blades are approximately twice that of a Wood Mizer and the saws are considerably more stable in transition wood densities.

Brewco Vertical Twin Scragg followed by a Brewco Horizontal Processing Red Alder at Mrytle Point, OR

Brewco Vertical Band Mill

Brewco Resaw with run around system

Brewco two saw edger

Figure D-1

Example Mill Layout
Brewco Inc.

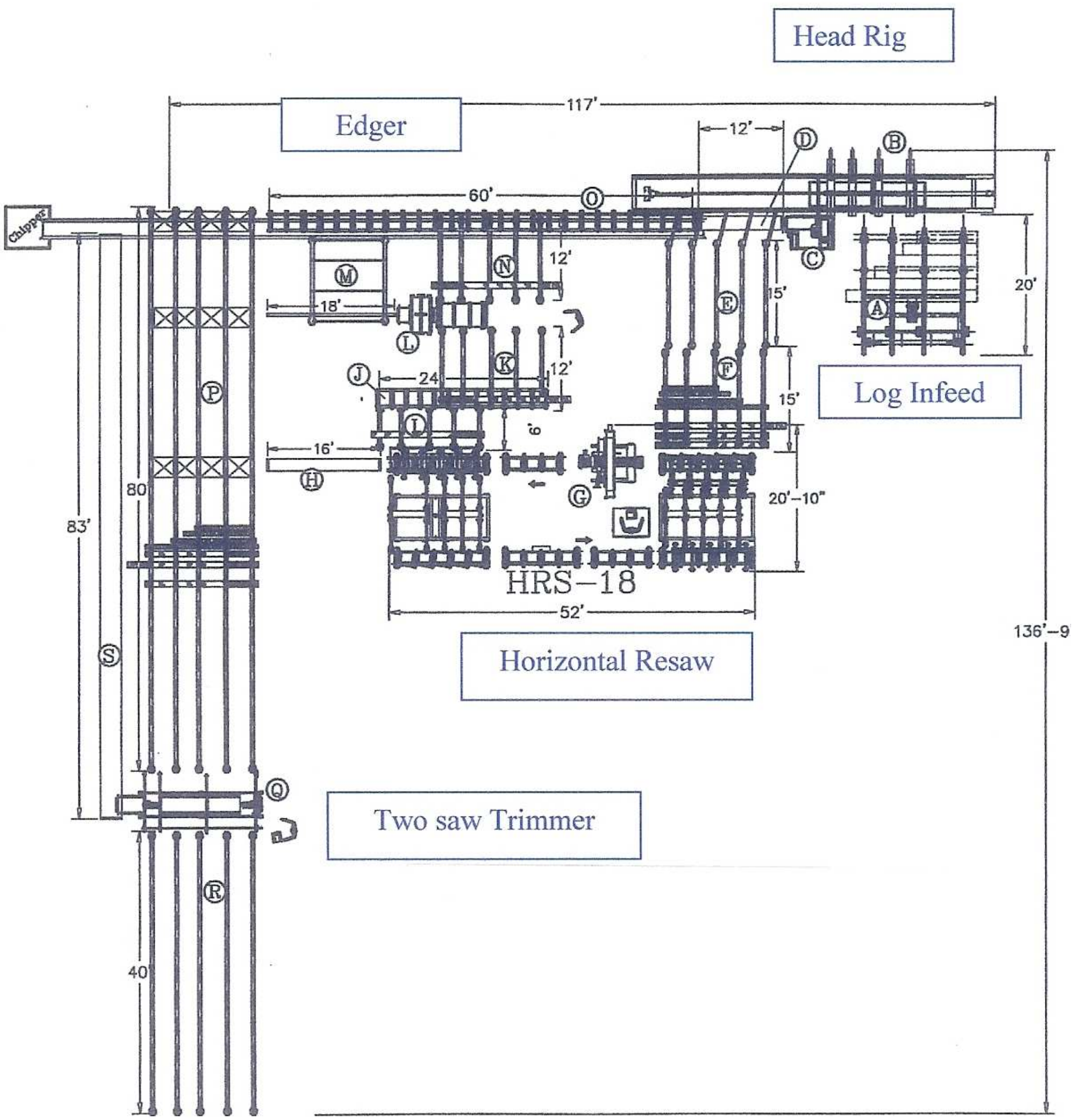


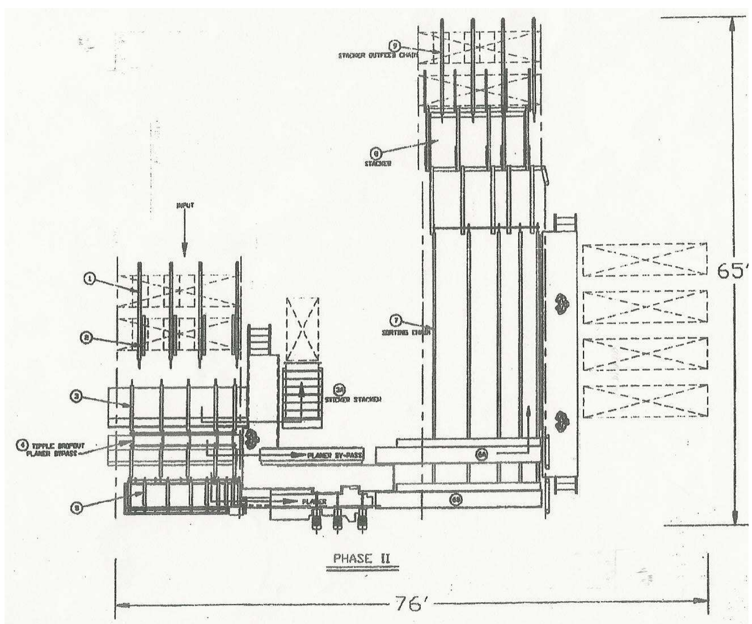
Figure C-1 depicts a mill with three principal machine centers plus a two saw end trimmer and a green chain. Typical crewing in this mill would be one person per center (4), two on the green chain, one supplemental utility employee, one lift truck driver and one log supply person. Rolling stock would include a Cat - 966 or equivalent log handler and a 10,000 pound fork lift. The estimated capital cost for the machinery depicted in this diagram is $1,000,000. Delivery costs and installation are estimated to cost an additional $1,000,000. This mill design would be capable of producing at least 20,000 board feet of lumber per 8 hour operating day. It could also be operated at 10,000 board feet per day without the horizontal re-saw.

Recent developments from Wood Mizer include a fixed base horizontal resaw (LT-300) capable of increased production but requiring a central location. Even more recently, Wood Mizer introduced the AWMV 4250 tilted band mil and carriage. This machine offers many advantages to higher production operations with lower capital investment and with thin kerf and narrow blades for less technical saw maintenance and sharpening.

2. <u>Lumber Handling and Finishing</u>

Virtually all lumber processing in Hawaii today is accomplished with hand stacking and the transfer of the units of product via fork lift to the next processing station. This is not competitively cost effective in comparison to lumber production in other parts of the world where mechanization of lumber stacking for drying and insertion of divider sticks between lumber courses is standard. Manual handling also increases the risks of injury and contributes to employee fatigue. It is also important to be able to selectively sort lumber by either thickness, width, length or by grade or quality. The installation of mechanized stacking and sorting can be connected with a surfacing machine such as a planer or moulder. Figure C-2 shows a layout design that combines, stickering, sorting, stacking and surfacing.

Figure D-2
Lumber Handling, Sorting and Stacking System



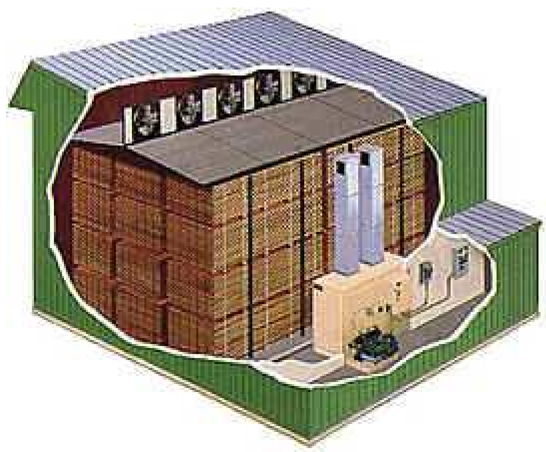
The estimated cost of the equipment for this line is $300,000. The line would require three employees. The lumber could be delivered to the line and taken away from the line by the same fork lift that serves the green chain at the sawmill.

3. Lumber Drying

Common practice in larger scale lumber operations is to use steam to heat the air that flows between the courses of lumber to remove the moisture from the boards. This is not the case in Hawaii because there are limited lumber volumes being processed and there are no existing steam generating operations that lumber operators have been able to access or invest in. Therefore, the predominant dry kiln facilities in Hawaii are dehumidification kilns as depicted in Figure C-3. Dehumidification works well for hardwood lumber drying. Dehumidification drying can be more energy efficient when drying directly from green lumber as opposed to when the lumber has previously air dried.

The biggest advantage to steam heated kilns comes from the burning of wood wastes such as bark and sawdust. This “closes the loop” on fiber utilization and eliminates disposal issues. Steam heated kilns are considerably more expensive to install because of the piping and support systems that also required. Well trained operators with steam heated kilns can perform more adjustments and corrections in the moisture removal and conditioning stages of the process. Steam heated kilns are recommended if the volume of production, the site and the investment capital are all available. An ideal operation would include a mixture of steam heated and dehumidification kilns.

Figure D-3



http://www.nyle.com

Dehumidification kilns can be built to handle lumber quantities that range from 500 to 50,000 board feet per unit. Figure C-4 shows kiln sizes for medium sized units. A properly sized kiln will dry hardwoods from 25% moisture in two to four weeks. A combination of 30,000 and 50,000 board foot units is recommended for matching variations in species, lumber sizes and market variability. The 30,000 board foot units should provide a proper mix of units for good scheduling flexibility. A 20,000 board foot per day sawmill with a 21 day drying schedule will necessitate a total installed kiln capacity of 400,000 board feet.

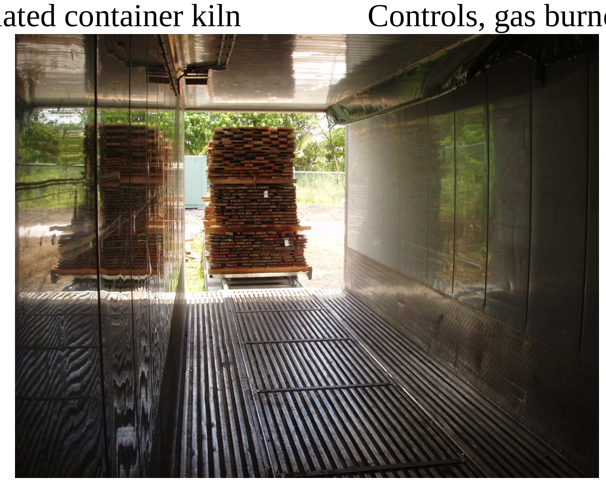
Another drying technology that fits Hawaii is a solar gas concept from an Australian company. This technology (http://www.solardry.com.au) utilizes solar collectors for heating water. The heated water (up to about 150 degrees Fahrenheit) is pumped to coils in the kiln chamber and fans circulate the air through the stickered lumber. The kilns are also equipped with a propane burner for back up in cooler periods and at night.

Four SG-50 Solar Gas Kilns in Australia.
http://www.solardry.com.au

Experimental Solar Gas Dry Kiln
Hawaii Island Hardwoods LLC
Kea'au, Hawaii

Infeed to 40' insulated container kiln

Controls, gas burner and pumps



Interior of drying chamber and lumber on cart ready for entry
Capacity of kiln is approximately 4,000 board feet

Advantages of dehumidification kilns:

a. Low capital cost.
b. Easier to deal with in the governmental permit process.
c. Energy efficiency when drying from green.

Disadvantages of dehumidification kilns:

a. High electricity costs in Hawaii.
b. Precise humidity control is difficult.
c. Controlling humidity during drying to equalize and condition lumber requires auxiliary equipment (steam or humidifier). Such capacity is essential with high-density hardwoods that have a tendency to collapse and caseharden if dried to quickly.
d. Length of time to dry will be extensive and will require numerous units.

Advantages of steam or hot water heated kilns:

a. Use of wood residues.
b. Ability to add humidity to the drying chamber during drying.
c. Solar heated water has low operational cost.

Disadvantages of steam or hot water heated kilns:

a. High capital cost.
b. Permitting requirements for boilers will probably be more stringent.

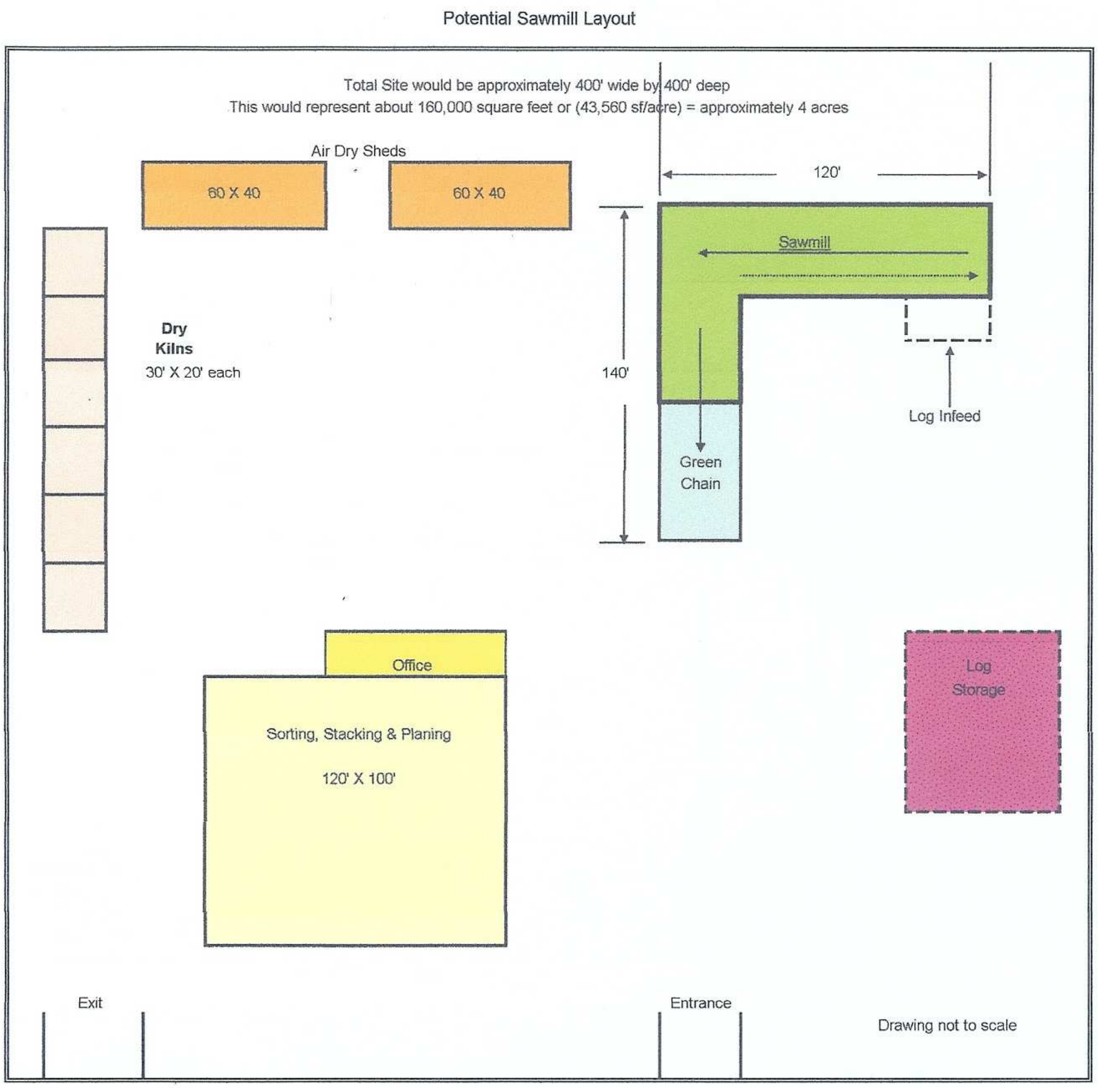
Advantages of insulated and closed solar gas kilns

a. Use of natural energy as the primary heat source
b. Good humidity controls.
c. Lower capital cost on the larger units.

Disadvantages of insulated and closed solar kilns:

a. Dependence on natural energy on inclement days.

D-4
Potential Overall Mill Layout



Appendix – A

Executive Summary:
Hawaii Hardwood Market Study
for
The State of Hawaii - Department of Land and Natural Resources
by
Hawaii Agriculture Research Center
Nicklos S. Dudley
&
JQuinn Company
James E. Quinn
December 9, 2004
http://www.hawaii.gov/dlnr/dofaw/pubs/Hawaii%20Hardwood%20Market%20Study.pdf

The market for higher value hardwood products in Hawaii is increasing significantly and consistently as it is in most areas of the country. Most of the high value applications are in hardwood flooring, furniture, cabinetry and other fixtures including doors, windows and moldings. The usage of high value or "appearance" type woods is focused largely in upper end housing and in repairs and remodeling.

Virtually all of the companies and individuals that were interviewed in this study expressed recognition of the demand for Hawaiian grown woods in the market place. Essentially all of the respondents also reported that the principal reasons for the relatively small amount of product in the marketplace are (1) inconsistent supply and (2) inconsistent quality. The inconsistency of supply comes about from the lack of committed resource to the potential producers. The inconsistencies in quality are predominantly the result of lumber drying issues, limited technology, lack of competitive processing facilities and the tendency for producers to force lower grade materials into the sales mixture to achieve the volume and additional revenue that is needed to survive as a business.

It has proved to be very difficult to capture a totally accurate number for hardwood imports. This is due to protection of proprietary and competitive information from retailers and distributors and it is also due to gross generalizations in units of measure from shippers. Nonetheless, we have found evidence of wood importation numbers and this is supplemented by selected information from our interviews. The net result being that we believe that total annual hardwood imports are in the range of 7,000,000 to10,000,000 Board Feet (BF). Additionally, we have opinion inputs and computed equivalents that cause us to believe that high quality locally grown products could displace as much as 2,000,000 board feet per year of this market segment.

The current principal imports from North American temperate hardwoods include Oak, Cherry, Ash, Maple and Poplar. The principal foreign imports are African Mahogany, Genuine Mahogany, Meranti, Teak and several Eucalypts. Weyerhaeuser is promoting Lyptus which is a Brazilian Eucalyptus hybrid with an appearance similar to *E. grandis* (Grandis) and *E. saligna* (Saligna). Generally speaking, the Hawaiian grown Robusta and Saligna display better color and character than does the Lyptus product. The characteristics of the African Mahogany (*khaya nyasica)* appear to be quite similar to Hawaiian grown *Toona ciliata* (Toon), which is not surprising since they are both relatives of the true Mahogany *(Swietenia macrophylla)*. It may also be possible to substitute some Hawaiian Eucalypts for African Mahogany if the processing and quality control are improved. Most of the foreign hardwoods are imported into mainland distributors initially and then they are reshipped to Hawaii.

The potential for the development of a significant forest products industry in Hawaii will be influenced to a great extent by the following:

Opportunities:

- There is a demand for Hawaiian grown woods in the market place.
- Significant quantities of hardwood lumber are being imported into the State.
- The demand for distinctive hardwood lumber is increasing.

Constraints:

- Inconsistent supply.
- Inconsistent manufacturing quality.
- Underdeveloped infrastructure for forest product processing.

Recommendation:

The limited amount of {Hawaiian} hardwood products that currently enter the marketplace display the potential to be as good as, or better than, many similar species from other areas. The State forest reserves possess the largest mature inventory of such timber. These stands of non-native species such as Robusta and Saligna also appear to possess the potential for very high quality “appearance grade” lumber.

The process of replacing imported hardwood lumber with locally grown and processed Hawaiian lumber is occurring now, however the scale is very limited. Presently, the demand for hardwood products exceeds the locally produced supply. For this imbalance to change several critical factors must be addressed. These factors are:

- Sufficient sustainable supply of forest resource to ensure economically efficient processing.
- Properly sized manufacturing facilities to match resource availability.
- Strong commitment to the technical issues of product quality.
- Effective marketing which will place high-value end use products in the market place.

The market for certified forest products is increasing in the US and in most other countries. Certification, particularly under the Principles and Criteria of the Forest Stewardship Council (FSC), carries with it the benefit of priority selection in the market and in some cases a premium over non-certified products. It also provides a generally effective means for social and environmental acceptance of proactive timberland management. FSC certification could enhance the access to forest resources in State forest reserves and ensure sustainable timber supply.

Appendix B

Data Tables

Table B-1
Sahalla Plantation Eucalyptus Saligna

					Log Scale			Lumber Tally			Intl BF/
Date	Species	Tree	DBH	Logs	Scribner	Int'l	Cubic	Actual BF	Nominal BF	Cubic Ft.	CF
7/25/2005	Saligna	1	18	10	820	910	131	1152	940	96	6.95
7/27/2005	Saligna	2	24	11	1340	1405	187	1761	1459	147	7.51
8/1/2005	Saligna	3	19	9	790	885	123	974	805	81	7.20
					2950	**3200**	**441**	**3887**	**3204**	**324**	7.26

Table B-2
Lumber Yield Summary
From Sahalla Trials

			MHH	Lumber Summary Hit and Miss Surfaced			
Date	Tree	DBH	Rough Tally	Pieces	2" Width	Thick	Length
7/25/2005	1	18	1152	158	2.75	0.99	9.5
7/27/2005	2	24	1761		2.75	0.99	9.5
8/1/2005	3	19	974	153	2.75	0.99	9.5
			3887				

		Lumber Summary Net Moulded Square Feet			
Tree		Pieces	Width	Thick	Length
1		144	2.275	0.78	9
2		207	2.275	0.78	9
3		144	2.275	0.78	9

Table B-3
Eucalyptus Saligna Veneer Slicing Trial

FIDR
Veneer Sort and
Shipment

Jul-06

Log Number	Final Length	Final Diameter	Net Scale Intl	Net Scale Scribner	Net Scale Cubic	Wt per	Est Gross Weight	Original Purchased Scale	Unit Cost	Cost per log
	ft	inches	bf	bf	cf	CF	pounds	bf before trimming	$/bf	$
Red 11-2	18.5	26	570	560	66	71	4,686	690	$0.20	$138.00
Red 11-3	18.5	23	445	415	53	71	3,763	545	$0.20	$109.00
Red 12-1	18.5	28	665	650	77	71	5,467	755	$0.20	$151.00
Green 1-1	18.5	28	665	650	77	71	5,467	800	$0.20	$160.00
Green 4-1	18.5	24	485	450	57	71	4,047	590	$0.20	$118.00
Green 19-1	16.5	23	445	415	53	71	3,763	470	$0.20	$94.00
S-2	18.5	23	445	415	53	71	3,763	470	$0.20	$94.00
			3720	3555	436	497	30,956	4320	$0.20	$864.00
Matson Weight		Pounds					37,100			
Matson Weight / CF		#/CF					85			
Logging									$300.00	$1,296.00
Hauling									$41.00	$177.12
Mill Site Handling and Loading				$75/hr	10 hrs					$750.00
Conen's freight to port										$215.16
Fumigation										$275.00
Matson Shipping										$4,039.20
										$7,616.48
			$/bf	$/bf	$/cf					
Unit costs			$2.05	$2.14	$17.47					

Table B-4
Eucalyptus Saligna Sliced Veneer Yield

			SQ Mtrs	SQ Ft	Board ft
Gross log shipment					3,720
Gross veneer output					
	9' and 10'		6,136	66,013	
	11',12,'15'		2,929	31,633	
	8'		957	10,336	
		Total	10,022	108,238	

29 - Square Feet of Veneer per Board Foot of Log Scale.

Table B-5
Eucalyptus Saligna Lumber Production

Ticket	Species	Log	Length	Eucalyptus Saligna Tally	Thickness	Saw Pattern	Shipped Sold
70001	E.Saligna	B 1-4	8	192	4/4		PP-627
70001	E.Saligna	B 1-5	9	156	4/4		PP-627
70001	E.Saligna	B 1-5	9	150	4/4		PP-627
70002	E.Saligna	B 2-2	8 & 10	554	4/4		PP-627
70003	E.Saligna	B 2-1	10	420	4/4		PP-627
70004	E.Saligna	B 2-1	10	430	4/4		PP-627
70005	E.Saligna	B 2-3	9 & 10	404	4/4		
70006	E.Saligna	G 4-1	10	400	4/4		
70007	E.Saligna	G 5-1	10	460	4/4		
70008	E.Saligna	G 5-3	7	252	4/4		
	E.Saligna	G 9-1	10	170	4/4		
70009	E.Saligna	G 4-2	10	420	4/4		PP-627
70010	E.Saligna	G 5-11			4/4		
		G 7-1		480	4/4		
		G 4-2			4/4		
		G 5-10			4/4		
70011	E.Saligna	S-1	7 & 7	520	4/4		
70012	E.Saligna	S-1	7	280	8/4		
70013	E.Saligna	G 4-4	10	456	8/4		
				5,744			
70014	E.Saligna	G-4-7	10	510	4/4		
70015	E.Saligna	G-5-4/BL6-6	10	520	4/4		PP-627
70016	E.Saligna	G-18-5	10	520	4/4		PP-627
70017	E.Saligna	BL-1-3	10	520	4/4		PP-627
				2,070			
June Total				7,814			
70018	E.Saligna			400			PP1018
70019		BL 1-3	10	460	9/4		Plack
		G 19-3	9	290	4/4		
				750			
70020	E.Saligna	G 19-3	10		4/4		Pelkey
		G 7-2	6		4/4		
		BL x	8		6X6		
		G 5-2,BL6-3,	10		4/4		
				940			
70021	E.Saligna	BLK 8-9	10	520	4/4		PP1018
70022	E.Saligna	BLK 8-9	10	520	4/4		
70025	E.Saligna	G-19-1	7	375	4/4		

Custom			14	280	8/4		
70041	E.Saligna	S-5,S-8	10	510	9/4		PP1018
70042	E.Saligna	S-7,S-5	10	500	4/4		PP1018
70043	E.Saligna	S-8,S-9		510	4/4		PP1018
70044	E.Saligna	R-11-5,S-9	10	500	4/4		PP1018
70045	E.Saligna	R-8-1	10	510	4/4		PP1018
70046	E.Saligna	R-1-5	10	480	4/4		PP1018
70047	E.Saligna	R-1-5	10	500	4/4		PP1018
70048	E.Saligna	G-1-6	8	210	6X6		Maner
				5,415			
				15,319			
70049	E.Saligna	E	10	490	4/4		
70050	E.Saligna	E	10	490	4/4		
70051	E.Saligna	12-3,12-11	10	490	9/4		PP
70052	E.Saligna		10	490			PP
70053	E.Saligna	EDGER	10	400	4/4		PP
70054	E.Saligna		10				
70055	E.Saligna	G-18-4	20	500	4/4		PP
70056	E.Saligna	BL21-1	10	500	4/4		PP
70057	E.Saligna	G-19-2	10	500	4/4		PP
70058	E.Saligna	MIX	13	600			Plack
70059	E.Saligna	14-2-1	14	500			
				4,960			
				20,279			
70067	E.S.	B19-5,8		420	9/4		GreenProd
		S9-4,G2-1					
70067	?			???			
70068							
70069	E.S.		10	420			PP
70070	E.S.		10	420			
70072	E.S		16	550			Plack
70023	E.S		8	630			Plack
70033	E.S.		13	450	4/4		
70034	E.S.		13	450	4/4		
70035	E.S.		13	450			
70036	E.S.		13	1500	7X10		Plack
70038	E.S.		13	450	4/4		
70039	E.S.		13	600	5X6	24pcs	Plack
70040	E.S.		13'&17'	511	5x6,4x6,7x10		Plack
70117	E.S.		13	1333	5x6		Plack
70118	E.S.		13	250	4/4		
70119	E.S.		19	266	2-7x12		Plack
70120	E.S.		7	400	4/4	qtrsawn	
70121	E.S.		7	400	4/4	qtrsawn	
70122	E.S.		7	400	4/4	qtrsawn	
70123	E.S.		7	400	4/4	qtrsawn	
70124	E.S.		8	450	4/4	qtrsawn	
70125	E.S.		8	450	4/4	qtrsawn	

70126	E.S.	8	450	4/4	qtrsawn
70127	E.S.	8	450	4/4	qtrsawn
70128	E.S.	8	450	4/4	qtrsawn
70095	E.S.	8	450	4/4	qtrsawn
70096	E.S.	8	450	4/4	qtrsawn
70105	E.S.	8	450	4/4	qtrsawn
70106	E.S.	8	450	4/4	qtrsawn
			13930		
			34,209		

Table B-6
Eucalyptus Robusta Yield Trial

Log Number	Length	Top Diameter	Butt Diameter	Intl Scale	Cubic Scale	Ratio Intl to Cubic
R-47	20'	17"	23"	240	44	5.45
R-12	9'	27"	30"	280	39	7.18
R-50	20'	16		235		

	17" R-47		27" R-12		16" R-50	
Width	Pieces	Lumber Yield	Pieces	Lumber Yield	Pieces	Lumber Yield
3	1	2.50		0.00	1	2.50
4		0.00		0.00	2	6.67
5	1	4.17		0.00	1	4.17
6	2	10.00	1	4.50	4	20.00
7	1	5.83	2	10.50	3	17.50
8	3	20.00	4	24.00	3	20.00
9	2	15.00	5	33.75	1	7.50
10	13	108.33	27	202.50	13	108.33
11	1	9.17	1	8.25		0.00
12	8	80.00	1	9.00	11	110.00
	32	**255.00**	41	**292.50**		**296.67**
Recovery ratio		1.06		1.04		1.26

Table 6a
Total Robusta Logs and Lumber Production

Log Scale

Eucalyptus Robusta - Ahualoa

Date	Log #	Length	Top Diameter	Butt Diameter	Scribner Scale	Intl Scale	Cubic Scale
11-Oct	1	20.5	19	24	310	335	53
	2	20.5	19	24	310	335	53
	3	20.5	20	30	350	370	63
	4	20.5	22	28	420	455	69
	5	20.5	16	17	200	235	30
	6	16.8	17	18	185	205	23
	7	20.5	14		140	175	
	8	21	17		235	267	
	9	13.9	16		120	130	
	10	17.5	14		110	135	
	11	9.7	30		330	325	
	12	9.3	28		290	280	
	13	10.2	14		70	80	
	14	10.5	12		50	55	
	15	20.5	13	18	120	150	25
	16	20.5	19		310	335	
	17	17.6	26		500	500	
	18	14.1	18		190	200	
	19	20.5	18		270	300	
	20	20.6	15		170	295	
	21	20.7	17		235	270	
	22	20.7	14		140	175	
	23	16.8	22		330	355	
	24	21.5	24		500	545	
	25	20	17		235	270	
	26	16.5	14	14	110	135	17
	27	21.5	17	22	235	270	44
	29	20.6	14		140	175	
	29	20.5	21		385	412	
	30	19.7	14		130	155	
	31	15.6	15		120	135	
	32	17.4	10		60	75	
	33	16	18		210	230	
	34	16	12		80	95	
	35	20.5	20		350	370	
	36	20.7	16		200	235	
	37	16.7	12		80	95	
	38	20.3	16		200	235	

	39	20.3	15		170	202	
	40	20.4	11		82	105	
	41	18.1	11		75	92	
	42	20.6	14		140	175	
	43	16.8	12		90	95	
	44	20	16		200	235	
	45	20.6	12		100	125	
	46	18.5	16		180	205	
	47	19	17		210	240	
	48	19.2	15		150	180	
	49	17.7	11		70	90	
	50	20.6	16		200	235	
	51	13.6	11		50	55	
	52	16.7	20		280	290	
	Total				10417	11718	

Eucalyptus Robusta Lumber Producton

Ticket Numbers	Date	Log	Length	Tally	Size/ Thickness
70074	27-Oct	R-1,13,14	10	320	2x6
70075	26-Oct	R-1,4	10	500	4/4
70076	26-Oct	R-1,4	10	500	4/4
70077	31-Oct	R-3,7	10	500	4/4
70078	2-Nov	R-2,8	10	500	4/4
70079	1-Nov	Edger	10	500	4/4
70080	2-Nov	R-10,19	10	500	4/4
70081	9-Nov	R-22,20,18	10	455	4/4
70082	9-Nov	R-18,15,21	10	455	4/4
70083	10-Nov	R-27,16	10	455	4/4
70084	10-Nov	R-27,16	10	455	4/4
70085	13-Nov	R-39,38	10	455	4/4
70086	14-Nov	R-44	10	455	4/4
70087	14-Nov	R-18,15,21	10	455	4/4
70088	15-Nov	R-19,25	10	455	4/4
70089	17-Nov	R-47,48	10	455	4/4
70090	17-Nov	R-12	10	455	4/4
70091	21-Nov	R-36,50	10	455	4/4
70092	27-Nov	R-42,5,30,35,42	10	685	5x6,3x6
70093	16-Nov	R-52	17	315	6/4
70094	28-Nov		10	455	4/4
70026	7-Dec		8	450	4/4
70027	7-Dec		8	450	4/4
70028	9-Dec		8	450	4/4
70029	12-Dec		8	450	4/4
70030	12-Dec		10	450	4/4
70031	12-Dec		10	450	4/4
70032	13-Dec		10	262	9/4
				12,742	
	Recovery/Yield			1.09	

Table B-7
Tropical Ash Log Data

Date	1/12/2006	Elevation:	5,330 feet
Source	State of Hawaii	Latitude	19-54.39n
Species	Tropical Ash	Longitude	155-19.21w

	Segment				
Number	Number	Length	Top Dia	Butt Dia	Ave Cubic Dia
Green					
1	1	18.6	17	21	19
	2	18.6	14	17	15.5
	3	15.6	10	14	12
Red					
2	1	18.7	14.5	19	16.75
	2	18.7	12	14.5	13.25
Orange					
3	1	18.7	19	22	20.5
	2	18.8	13	19	16
	3	7.7	12	12	12
	4	5.7	12	12	12
White					
4	1	18			cull
	2	9	18	19	18.5
Blue					
5a	1	17.5	11	11	11
	2	18.7	9	11	10
Yellow	3	5.2	9	9	9
5b	4	18.7	12	12	12
	5	18.7	9	12	10.5
	6	14.7	8	9	8.5

Table B-8
Tropical Ash
Logging, Hauling, Processing and Sales

	Unit Costs	Units	Time hrs	Volume board ft	Costs	Total Business	Notes
Logging and hauling:							
Stumpage price (DLNR)	$0.20	bd ft		1690		$338	DLNR did not charge for the stumpage.
Permit					$10		
Logging					$600		
Hauling					$600		
Total stumpage, logging and hauling	$0.72				$1,210	$1,548	
With stumpage at $.20	$0.92						
Processing (at Brauner Woodworks)							
Log Volume (per Hal Brauner)				1700			
Lumber Tally (per Hal Brauner)				2200			
Lumber Tally (per Jim Quinn)				2357			
Sawing	$85.00	per hour	13		$1,105.00		
Stick/Dry	$0.45	bd ft			$990.00		
Planing	$85.00	per hour	6		$510.00		
Straight line ripping and grading	$85.00	per hour	6.5		$552.50		
Moulding	$125.00	per hour	8.5		$1,062.50		
Total processing	$1.79	bd ft			$4,220.00		
Total Logging and Processing					$5,430.00	$6,978	

Income

	Unit Prices	Square Feet	Sales Realizations	
Yield				
Select 8/4	$4.15	50	$207.50	
Select 4/4	$4.15	352	$1,460.80	
Paneling/Flooring	$3.85	1100	$4,235.00	
Planed 4/4		246		
Average realization	$3.38	1,748	$5,903.30	
Gross Profit			$473.30	-$1,074.70

Table B-9
Toon Log Scale

Date	Log #	Length	Top Diameter	Butt Diameter	Intl Scale	Cubic Scale	Bd Ft / CF
6-Sep	1-1	21.5	18	21	300	40	7.50
	1-2	20.5	16	18	235	31	7.58
	2-1	20.5	20		370		
	2-2	20.5	14		175		
	3-1	20.5	14		175		
	3-2	20.5	12		125		
	4-1	20.5	18	24	300	48	6.25
	4-2	18.5	14	18	155	25	6.20
	5-1	20.5	15	20	150	31	4.84
	5-2	20.5	10		85		
	6-1	20.5	17	19	270	35	7.71
	6-2	20.5	16		235		
	6-3	8.75	10		30		
	7-1	20.5	17	19	270	35	7.71
	7-2	12.1	16		130		
	7-3	12.1	12		70		
7-Sep	8-1	20.5	15		205		
	8-2	20.5	12		125		
	9-1	22.3	12		140		
	10-1	20.5	19		335		
	10-2	9.5	18		125		
	11-1	20.5	18		300		
	11-2	20.5	14		175		
	11-3	5	13		30		
	12-1	20.5	17	20	270	35	7.71
	12-2	20.2	13		150		
	13-1	20.5	11		105		
	13-2	20.5	10		85		
	14-1	20.5	13	14	150	18	8.33
	14-2	20.5	11	13	105	16	6.56
	15-1	20.5	19	22	335	44	7.61
	15-2	12.9	11		60		
	15-3	12.1	13		85		
	15-4	20.5	10		85		
	16-1	20.5	17		270		
	16-2	20.5	14		175		
12-Sep	17	16.7	20	21	290	35	8.29
	18	20.7	21	24	415		
	19	20.5	10		85		
	20	20.3	16		235		

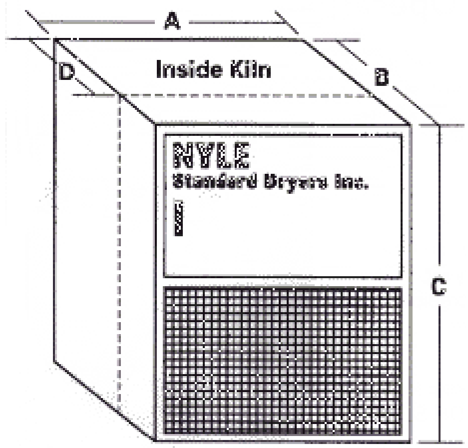
	21	20.1	12		125		
	22	20.1	12		125		
	23	20.5	14		175		
	24	20.2	12		125		
	25	20.2	10		85		
	26	20.5	7		60		
	27	20.5	9		60		
	28	20.5	26	28	640	80	8.00
14-Sep	29	16.5	9		55		
	30	16.5	8		50		
18-Sep	31	20.5	9	13	45	13	3.46
	32	20.5	11		105		
	33	20.5	9		45		
	34	20.5	10		85		
18-Sep	35	20.5	17		267		
	36	20.4	17		267		
	37	14.5	7		10		
	38	18.75	13		132		
	39	20.4	10		85		
	40	20.5	10		85		
	41	20.5	10		85		
	42	10.75	12		55		
	43	8	9		25		
	44	20.5	8		45		
	45	20.5	7		40		
	46	20.5	10		85		
	47	20.5	26	27	640	76	8.42
	48	20.5	6		40		
	49	14	9		45		
	50	18	12		110		
	51	11.5	10		40		
Total					11246		

Table B-10
Toon Lumber Production

Ticket	Date	Log	Length	Tally	Thickness	Customer	Moisture
70060	14-Sep	28-17	10	600	9/4	PP	Grn
70061	15-Sep	28-17-18	10	500	4/4	PP	Grn
70062	19-Sep	1-1/ 1-2/ 2	10	525	9/4	PP	Grn
70063	19-Sep		10	525	9/4	PP	Grn
70064	19-Sep	EDGER	10	400	4/4	PP	Grn
70065	19-Sep	4-2	10	525	9/4	PP	Grn
				3075			

Figure B-1
Nyle Dehumidification Kilns

Medium Lumber Systems



	L300	L500	L1200S
A	36" (91 cm)	44" (112 cm)	64" (163 cm)
B	44" (112 cm)	45" (114 cm)	60" (152 cm)
C	51" (130 cm)	51" (130 cm)	51" (130 cm)
D	19" (48 cm)	29" (74 cm)	39" (99 cm)

Specs	L300	L500	L1200S
Compressor Nominal HP	3	5	15
Internal Blower Motor HP	1	1.5	3
Auxiliary Electric Heat (*1)	8 KW	12 KW	48 KW
Circulating Fans (*2)	3 @ 1/2 HP	5 @ 1/2 HP	4 @ 2 HP
Fan Diameter	24" (61 cm)	24" (61 cm)	30" (75 cm)
Reversing Fans	Optional	Optional	Standard
Overtemperature Vents	Two Auto	Two Auto	Two Auto
Operating Temperature Range	70' to 160' F (21' to 72' C)	70' to 160' F (21' to 72' C)	70' to 160' F (21' to 72' C)
Electric-Volts/Phase/Hertz	220/1/60 220/1/50 220/3/60 220/3/50 460/3/60 380/3/50 575/3/60	220/1/60 220/1/50 220/3/60 220/3/50 460/3/60 380/3/50 575/3/60	220/3/60 220/3/50 460/3/60 380/3/50 575/3/60
Discharge Duct Riser	Included	Included	Included
Nominal Water Removal Per 24 Hrs.	420 lbs. (191 kg)	720 lbs. (327 kg)	1650 lbs. (750 kg)
Load Capacity	2,500-8,000 BD. FT (6-18 cu meters)	4,000-15,000 BD. FT (9-35 cu meters)	10,000-30,000 BD. FT (23-70 cu meters)

Figure B -2
Nyle Kiln Energy Usage

CAPACITY CHART

This chart can be used to compare drying times, annual production, and electric cost for drying a load. Remember, a Nyle kiln is an investment, and should be looked at as such. The return on the investment have to take into account the variances in lumber pricing, the cost of the kiln chamber, and the amount of lumber dried during a year. This chart will prove close to what you will see in a majority of applications.

Different types of wood are dried at different rates, we have grouped similar drying woods in this chart to reflect that. As some woods, such as softwoods, need to be dried fast in order to avoid mold and stain, while some hardwoods, such as Oak have to be dried slowly to avoid checks and honeycomb.

Group 1—Pine, Fir, Cedar, Poplar, Aspen (softwoods and fast drying hardwoods)
Group 2—Cherry, Birch, Maple, Ash, Beech, Walnut, Elm (medium drying hardwoods
Group 3—Oak (Red and White), Rock Elm (slow drying hardwoods)
MBF= 1000 Board Feet (2.36m^3)

			Moisture Content Green to 7%			Moisture Content 30% to 7%		
Model	Wood Group	Load Size BF	Annual Production BF	Drying Days	Drying Cost per MBF	Annual Production BF	Drying Days	Drying Cost per MBF
L50	1	300	7,800	13	$41.67	27,000	4	$11.83
	2	600	12,000	18	$39.60	43,800	7	$14.74
	3	1000	10,000	36	$39.78	24,000	15	$16.57
L200	1	1500	43,500	12	$39.84	180,000	3	$10.40
	2	3000	48,000	22	$37.14	135,000	8	$14.09
	3	4000	40,000	35	$39.88	88,000	16	$17.31
L300	1	2000	80,000	9	$39.76	208,000	3	$11.86
	2	6000	114,000	19	$29.63	198,000	11	$16.46
	3	8000	96,000	30	$34.72	192,000	15	$17.65
L500	1	3000	135,000	8	$38.89	360,000	3	$15.00
	2	8000	320,000	22	$40.72	264,000	8	$15.41
	3	12000	144,000	30	$41.50	312,000	14	$17.65
L1200S	1	10000	400,000	9	$37.64	1,200,000	3	$13.26
	2	20000	400,000	18	$39.32	1,040,000	7	$14.63
	3	30000	360,000	28	$42.25	900,000	12	$17.42

This chart is based on 9¢/kWh electricity, 50°F. outside temperature, building sized for the load size listed and as a separate building. This chart assumes electric pre–heat. The drying times are based on drying 4/4 (1", 25mm) lumber. Thicker lumber generally will take longer to dry, and has to be dried slower.

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It is important to note that Figure B-5 is based upon $.09 / kwh power rate. In Hawaii, we are more likely to experience power rates in the range of $.30 / kwh.

Appendix C

Log Scaling and Conversion Factors

Figure C-1
Log Scale

	Scribner – Board Feet			International - BF							Cubic - CF						
	Lengths			*Lengths*							*Lengths*						
DIA	**8**	**14**	**20**	**8**	**10**	**12**	**14**	**16**	**18**	**20**	**8**	**10**	**12**	**14**	**16**	**18**	**20**
10	30	40	70	30	35	45	55	65	75	85	4	5	7	8	9	10	11
12	40	70	100	45	55	70	85	95	110	125	6	8	9	11	13	14	16
14	60	100	140	65	80	100	115	135	155	175	9	11	13	15	17	19	21
16	80	140	200	85	110	130	155	180	205	235	11	14	17	20	22	25	28
18	110	190	270	110	140	170	200	230	265	300	14	18	21	25	28	32	35
20	140	240	350	135	175	210	250	290	330	370	17	22	26	33	35	39	44
22	170	290	420	170	215	260	305	355	405	455	21	26	32	40	42	48	53
24	210	350	500	205	255	310	370	425	485	545	25	31	38	47	50	57	63
26	250	440	620	240	305	370	435	500	570	640	29	37	44	55	59	66	74
28	290	510	730	280	355	430	510	585	665	745	34	43	51	64	68	77	86
30	330	570	820	325	410	495	585	675	765	860	39	49	59	74	79	88	98
32	370	640	920	375	470	570	670	770	875	980	45	56	67	84	89	101	112
34	400	700	1000	425	535	645	760	875	990	1110	50	63	76	88	101	113	128
36	460	810	1150	475	600	725	855	980	1115	1245	57	71	85	99	113	127	141
38	540	930	1330	535	670	810	955	1095	1245	1390	63	79	95	110	126	142	158
40	600	1050	1500	595	750	900	1060	1230	1380	1540	70	87	105	122	140	157	175
42	670	1170	1680	655	825	995	1170	1345	1525	1705	77	96	115	135	154	173	192
44	740	1290	1850	725	910	1095	1290	1480	1675	1870	84	106	127	148	169	190	211
46	790	1390	1980	795	995	1200	1410	1620	1835	2050	92	115	138	162	185	208	231
48	860	1510	2160	865	1090	1310	1540	1770	2000	2235	101	126	151	176	201	226	251
50	940	1640	2340	940	1185	1425	1675	1920	2175	2425	109	136	164	191	218	245	273

Figure C-2

Log Ratios

Conversion Factors Log Relationships

	Log #	Length Feet	Top Dia Inches	Butt Dia Inches	Scribner Scale BF	Intl 1/4 Scale BF	Cubic Scale CF	Ratio BF/CF	Cubic Meters at 35
Robusta	1	20.5	19	24	310	335	53	6.32	1.51
	2	20.5	19	24	310	335	53	6.32	1.51
	3	20.5	20	30	350	370	63	5.87	1.80
	4	20.5	22	28	420	455	69	6.59	1.97
	5	20.5	16	17	200	235	30	7.83	0.86
	6	16.8	17	18	185	205	23	8.91	0.66
	15	20.5	13	18	120	150	25	6.00	0.71
	26	16.5	14	14	110	135	17	7.94	0.49
	27	21.5	17	22	235	270	44	6.14	1.26
Saligna	1	16	35	42	860	930	107	8.69	3.06
	4	9	21	26	155	365	43	8.49	1.23
	6	15	16	20	150	170	21	8.10	0.60
	8	16	19	24	245	260	31	8.39	0.89
	3	17	23	23	400	415	50	8.30	1.43
	3	16	37		995	1040	120	8.67	3.43
	6	14	33		670	715	70	10.21	2.00
Toon	1-1	21.5	18	21	270	300	40	7.50	1.14
	1-2	20.5	16	18	200	235	31	7.58	0.89
	4-1	20.5	18	24	270	300	48	6.25	1.37
	4-2	18.5	14	18	130	155	25	6.20	0.71
	5-1	20.5	15	20	120	150	31	4.84	0.89
	6-1	20.5	17	19	235	270	35	7.71	1.00
	7-1	20.5	17	19	235	270	35	7.71	1.00
	12-1	20.5	17	20	235	270	35	7.71	1.00
	14-1	20.5	13	14	120	150	18	8.33	0.51
	14-2	20.5	11	13	85	105	16	6.56	0.46
	15-1	20.5	19	22	310	335	44	7.61	1.26
	17	16.7	20	21	280	290	35	8.29	1.00
	18	20.7	21	24	385	415	53	7.83	1.51
	28	20.5	26	28	620	640	80	8.00	2.29
			583			10270	1345	7.64	38.43
	Avg Dia		**20.10**		**BF/M3**	**267.25**			

Figure C-3

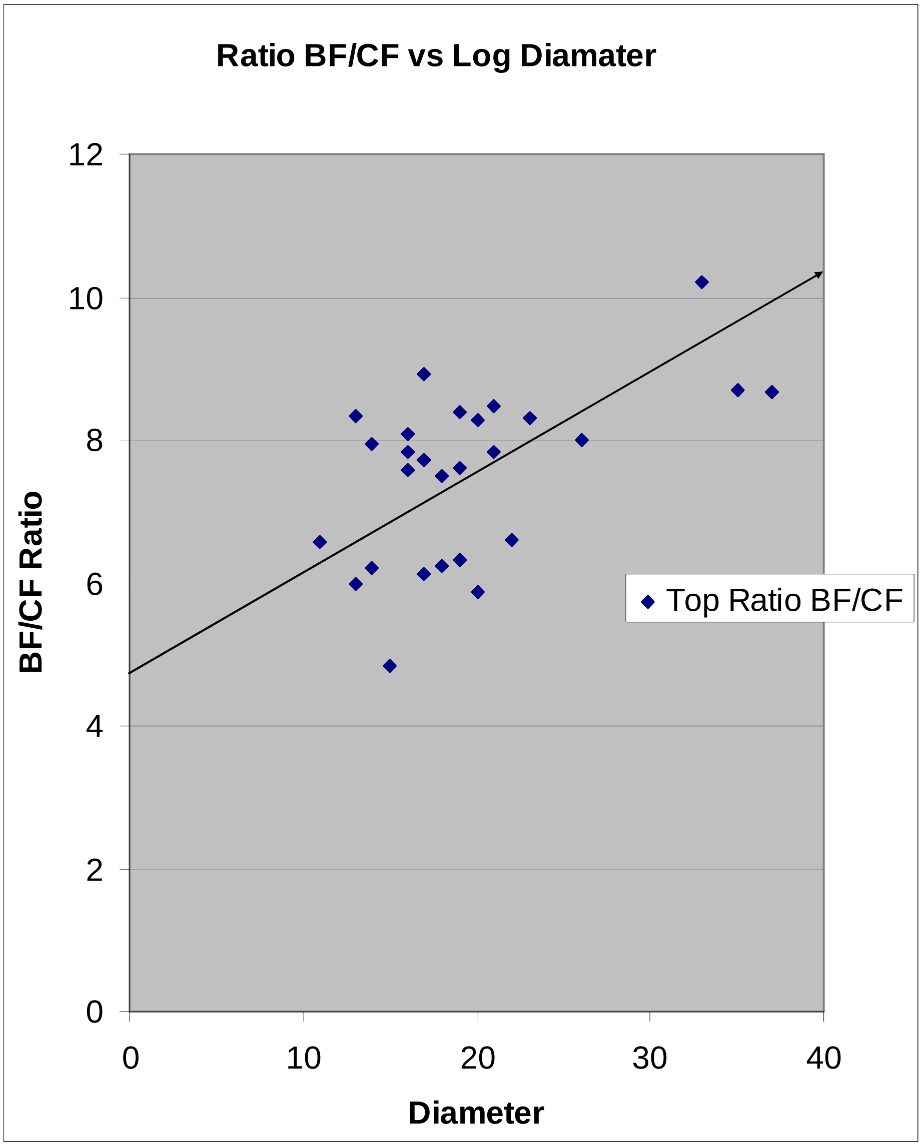
Ratio BF/CF vs Log Diamater
12
10
8
6
4
2
0
0
10
20
30
40
BF/CF Ratio
Diameter
Top Ratio BF/CF

Figure C-4

Wood Products Conversion Factors

	Cubic Meters	Board Feet		
		General Standards:		
Lumber	1	424		
Log	1	180	7"-10"	
		220	10"-14"	
		250	15" plus	
Cubic Feet to Cubic Meters				
1 M3 =		35	CF	
		Field Trials:		
			Top Diameter	BF/ CM
			11	270
Avg Dia	20.10		13	210
BF/M3	267.25		13	263
			14	278

Appendix D

Inventory

Table D-1
Timber Inventory Acreage by Owner, Island and Species

Table 1
County Landowner Species
by acre

County	Name	Property	Total Acres	Alnus 'nepal-ensis	Casuarina equisetifolia	Cryptomeria japonica	Cupressus macrocarpa	Eucalyptus citriodora	Eucalyptus deglupta	Eucalyptus globulus	Eucalyptus grandis	Eucalyptus microcorys	Eucalyptus mixed	Eucalyptus robusta	Eucalyptus rostrata	Eucalyptus saligna	Flindersia brayleyana	Fraxinus uhdei	Grevillia robusta	Lopho - stemon confertus	Pinus mixed	Toona ciliata	Various Mixed	TUP *
				Nepal Alder	Horse Tail or Iron wood	Sugi - Japanese cedar	Monterey cypress	Lemon-gum	Bagras	Bluegum	Rosegum	Tallowwood		Swamp-mahogany	River Redgum	Sydney Bluegum	Queensland Maple	Tropical Ash	Silk - Oak	Brush Box		Australian Red Cedar or Toon		
Hawaii	DHHL	Hamakua Forest	934			7	14						342	472		47						7		45
Hawaii	Hancock	Fund 03	12,704								12,704													
Hawaii	Hancock	Fund 04	3,731								3,731													
Hawaii	Hawaii Forest Preservation	Hamakua	1,000											1,000										
Hawaii	Kamehameha Schools	Honaunau Forest	1,516													282		629				605		
Hawaii	Land Division	Hamakua Forest	1,407		71			11		996		8	150	83		26		12				24		26
Hawaii	Mauna Kea Ranch	Mauna Kea Ranch	400							400														
Hawaii	Parker Ranch	Parker	500										500											
Hawaii	Pinnacle	Fund 05	4,474								4,474													
Hawaii	State of Hawaii	Hamakua Forest	3,894		40	137						42	782	1,911	22	354	14	287	125	24		95		61
Hawaii	State of Hawaii	Waikea Forest	11,254	24		102			54					279		3,750	1,485	2,060				3,500		
Kauai	Hawaiian Mahogany Inc.	Misc	2,909						2,902															
Kauai	Joyce Doty	Misc	189																				189	
Maui	Haleakala Ranch	Puu Pahu/ Mountain Pastures	222							222														
Maui	Haleakala Ranch	Waikamoi	357																		357			
Maui	Haleakala Ranch	Waikamoi Preserve	309																		309			
Maui	Maui Land and Pineapple Co.	Field12/10 Mauka	104			104																		
Maui	State of Hawaii	Kula FR	1,942																		1,942			
Maui	State of Hawaii	WMFR/Haelaau	62			62																		
Maui	State of Hawaii	WMFR/Poelua	72																		72			
Maui	Thompson Ranch	Waiohuli	200										200											
Maui	Ulupalakua Ranch	Misc	160										160											
	Total		48,340	24	111	412	14	11	2,956	1,618	20,909	50	2,134	3,745	22	4,459	1,499	2,988	125	24	2,680	4,231	189	132

Total by County																						
Hawaii		41,814	24	111	246	14	11	54	1,396	20,909	50	1,774	3,745	22	4,459	1,499	2,988	125	24	0	4,231	0	132
Kauai		3,098	0	0	0	0	0	2,902	0	0	0	0	0	0	0	0	0	0	0	0	0	189	0
Maui		3,428	0	0	166	0	0	0	222	0	0	360	0	0	0	0	0	0	0	2,680	0	0	0

* Temporarily Un Planted

Table D-2
Timber Annual 10 Year Harvest Volume

Table 2

Estimated Annual Harvest over a 10 Year Period

County	Name	Property	Total Annual Ft3Volume	Alnus nepalensis	Casuarina equisetifolia	Cryptomeria japonica	Cupressus macrocarpa	Eucalyptus citriodora	Eucalyptus deglupta	Eucalyptus globulus	Eucalyptus grandis	Eucalyptus microcorys	Eucalyptus mixed	Eucalyptus robusta	Eucalyptus rostrata	Eucalyptus saligna	Flindersia brayleyana	Fraxinus uhdei	Grevillia robusta	Lophostemon confertus	Pinus mixed	Toona ciliata	TUP *	Various Mixed
				Nepal Alder	Horse Tail or Iron wood	Sugi - Japanese cedar	Monterey cypress	Lemon-gum	Bagras	Bluegum	Rosegum	Tallow - wood		Swamp-mahogany	River Redgum	Sydney Bluegum	Queensland Maple	Tropical Ash	Silk - Oak	Brush Box		Australian Red Cedar or Toon		
Hawaii	DHHL	Hamakua Forest	634,763			4,124	2,450						168,715	407,341		47,833						4,299	0	
Hawaii	Hancock	Fund 03	6,987,200								6,987,200													
Hawaii	Hancock	Fund 04	1,678,950								1,678,950													
Hawaii	Hawaii Forest	Hamakua	954,100											954,100										
	Preservation																							
Hawaii	Kamehameha	Honaunau Forest	133,607													61,166		35,476				36,966		
	Schools																							
Hawaii	Land Division	Hamakua Forest	908,085		42,337			3,850		575,835		10,734	136,985	100,214		19,188		4,200				14,741	0	
Hawaii	Mauna Kea Ranch	Mauna Kea Ranch	210,000							210,000														
Hawaii	Parker Ranch	Parker	210,000										210,000											
Hawaii	Pinnacle	Fund 05	2,348,850								2,348,850													
Hawaii	State of Hawaii	Hamakua Forest	2,755,682		23,852	80,720						46,421	427,966	1,588,710	18,212	328,523	3,585	131,412	25,665	22,267		58,349	0	
Hawaii	State of Hawaii	Waikea Forest	1,968,969	11,894		6,304			10,313					131,321		961,426	294,275	185,812				367,625		
Kauai	Hawaiian	Misc																						
	Mahogany Inc.																							
Kauai	Joyce Doty	Misc																						
Maui	Haleakala Ranch	Puu Pahu/																						
		Mountain Pastures																						
Maui	Haleakala Ranch	Waikamoi	110,670																		110,670			
Maui	Haleakala Ranch	Waikamoi Preserve	105,060																		105,060			
Maui	Maui Land and	Field12/10 Mauka																						
	Pineapple Co.																							
Maui	State of Hawaii	Kula FR																						
Maui	State of Hawaii	WMFR/Haelaau																						
Maui	State of Hawaii	WMFR/Poelua																						
Maui	Thompson Ranch	Waiohuli																						
Maui	Ulupalakua Ranch	Misc																						
Total	Cubic Feet		19,005,936	11,894	66,189	91,148	2,450	3,850	10,313	785,835	11,015,000	57,156	943,667	3,181,686	18,212	1,418,135	297,861	356,899	25,665	22,267	215,730	481,979		
				0.06%	100.00%	0.48%	0.01%	0.02%	0.05%	4.13%	57.96%	0.30%	4.97%	16.74%	0.10%	7.46%	1.57%	1.88%	0.14%	0.12%	1.14%	2.54%		
Total	Board Feet	(using 6 bd ft /cf)	47,945,617	71,366	397,136	546,890	14,700	23,100	61,878	4,715,012		342,934	5,661,999	19,090,113	109,270	8,508,812	1,787,164	2,141,395	153,988	133,603	1,294,380	2,891,876		
		(using 5 bf/cf)	55,075,000								55,075,000													

* Temporarilay Un Planted

Table D-3
Kauai Timber Stands

Hawai'i Forestry Management Consultants

PO Box 351
Lawai, Hawaii
96765-0351

Phone/Facsimile:
808 332-5200

email: forestry@hawaiiantel.net

Tax Map Key	Owner	Acres		Address
2-3-009-006-0000	Terry Allen	1.5		
2-3-009-007-0000	Terry Allen	1.0		
2-3-009-008-0000	Terry Allen	3.0		
2-3-009-009-0000	Terry Allen	7.1		
1	**Terry Allen**	**12.7**		**P.O. BOX 947 Kalaheo, 96741**
2-5-006-012-0002	Michael Ceurvorst	7.5	**	
2	**Michael Ceurvorst**	**7.5**		**Grenville House I-11 1-3 Magazine Gap Road, Hong Kong**
2-5-006-029-0004	Mark P. Smith	2.5	**	
3	**Mark P. Smith**	**2.5**		**P.O. BOX 1026 Koloa, HI. 96756**
2-6-001-019-0000	Gay Davis	5.3	**	
4	**Gay Davis**	**5.3**		**P.O. BOX 223102 Princeville, HI. 96722**
2-7-001-001-0000	Hawaiian Mahogany Inc.	64.2		
2-7-001-002-0000	Hawaiian Mahogany Inc.	299.6	**	
2-7-001-004-0000	Hawaiian Mahogany Inc.	273.0	**	
2-7-001-005-0000	Hawaiian Mahogany Inc.	245.0		
2-7-002-001-0000	Hawaiian Mahogany Inc.	1,162.4	**	
2-8-001-003-0000	Hawaiian Mahogany Inc.	82.3		
2-9-002-001-0000	Hawaiian Mahogany Inc.	312.0	**	
3-4-001-001-0000	Hawaiian Mahogany Inc.	316.4	**	
3-4-006-001-0000	Hawaiian Mahogany Inc.	147.4	**	
5	**Hawaiian Mahogany Inc.**	**2,902.2**		**P.O. BOX 649 Lawai, HI. 96765**
4-4-002-118-0002	Jane Sezak	2.4		
6	**Jane Sezak**	**2.4**		**P.O. BOX 1555 Kapaa, HI. 96746**
4-6-009-035-0001	David Rovinsky	1.1		
7	**David Rovinsky**	**1.1**		**P.O. BOX 1808 Lihue, HI. 96766**
4-6-033-029-0000	Fred Peel	2.5		
8	**Fred Peel**	**2.5**		**1740 A Mauna Ikena Road Kapaa, HI. 96746**
4-9-009-009-0008	Donald Olson	9.2		
9	**Donald Olson**	**9.2**		**47466 San Clemente Terrace Freemont,CA. 94539**
5-1-005-004-0000	Joyce Doty	138.9	**	
5-1-005-006-0000	Joyce Doty	2.3		
5-1-005-022-0000	Joyce Doty	30.3		
5-1-005-102-0000	Joyce Doty	4.4	**	
5-1-005-110-0000	Joyce Doty	6.2		
5-1-005-111-0000	Joyce Doty	6.9		
10	**Joyce Doty**	**189.0**		**P.O. BOX 582 Kilauea, HI. 96754**

Table D-4
Kauai Timber Stands

Tax Map Key	Owner	Acres		Address
5-1-005-109-0000	Robert Schaefer	2.3	**	
11	**Robert Schaefer**	**2.3**		**P.O. BOX 3151 Lihue, HI. 96766**
5-1-006-020-0002	Eugene Taylor	3.3	**	
12	**Eugene Taylor**	**3.3**		**4471 D Kapuna Road Kilauea, HI. 96754**
5-1-006-023-0003	John & Claudia Niemiec	1.3	**	
13	**John & Claudia Niemiec**	**1.3**		**4333 Kapuna Road Kilauea, HI. 96754**
5-2-002-011-0003	Neal Norman	16.8	**	
14	**Neal Norman**	**16.8**		**52151 Kuhio Hwy. 3 Hanalei, HI. 96714**
5-2-012-019-0001	David Steinmann	6.5		
15	**David Steinmann**	**6.5**		**1185 Park Avenue Apt. 4H New York,NY 10128 1309**
5-2-012-019-0005	Adam Dunsby	6.8		
16	**Adam Dunsby**	**6.8**		**65 Redding Road Easton, CT. 06612**
5-2-022-019-0004	Constantin Samoilov	4.2		
17	**Constantin Samoilov**	**4.2**		**P.O. BOX 824 Chattaroy, WA. 99033**
5-3-008-019-0001	Charlie Bass	4.5		
5-3-008-019-0002	Charlie Bass	4.0		
5-3-008-019-0003	Charlie Bass	4.0		
5-3-008-019-0004	Charlie Bass	6.1		
5-3-008-019-0005	Charlie Bass	5.2		
18	**Charlie Bass**	**23.8**		**3788 Ahonui Place Princeville, HI. 96722**
5-3-008-022-0001	James Gair	4.5	**	
19	**James Gair**	**4.5**		**P.O. BOX 663 Kilauea, HI. 96754**
5-3-008-022-0002	Roy Chambers	2.9		
20	**Roy Chambers**	**2.9**		**P.O. Box 1631 Hanalei, HI. 96714**
5-3-008-022-0003	Robert Isom	2.3	**	
21	**Robert Isom**	**2.3**		**P.O. BOX 223201Princeville HI. 96722**
5-3-008-022-0004	Wendy Devore	3.9	**	
22	**Wendy Devore**	**3.9**		**4170 Kalani Place Princeville, HI. 96722**
5-3-008-022-0005	Greg Fassett	5.3	**	
23	**Greg Fassett**	**5.3**		**1244 N Coast Hwy. Laguna Beach CA.. 92651**
	Total Acres	**3,218.2**		

** **denotes portion of larger parcel acreage**

Forestry people
County of Kauai

Tax Map Key					
2-3-009-006-0000	Terry Allen	332-9801	1.510	P.O. BOX 947 Kalaheo, 96741	
2-3-009-007-0000	Terry Allen	332-9801	1.030	P.O. BOX 947 Kalaheo, 96741	
2-3-009-008-0000	Terry Allen	332-9801	3.030	P.O. BOX 947 Kalaheo, 96741	
2-3-009-009-0000	Terry Allen	332-9801	7.110	P.O. BOX 947 Kalaheo, 96741	
2-5-006-012-0002	Michael Ceurvorst	652-0791	7.500	Grenville House I-11 1-3 Magazine Gap Road	
2-5-006-029-0004	Mark P. Smith	332-7240	2.477	P.O. BOX 1026 Koloa, HI. 96756	
2-6-001-019-0000	Gay Davis	827-8045	5.306	P.O. BOX 223102 Princeville, HI. 96722	
2-7-001-001-0000	Hawaiian Mahogany Inc.	332-8570	64.200	P.O. BOX 649 Lawai, HI. 96765	halekua@aloha.net
2-7-001-002-0000	Hawaiian Mahogany Inc.	332-8570	299.550	P.O. BOX 649 Lawai, HI. 96765	halekua@aloha.net
2-7-001-004-0000	Hawaiian Mahogany Inc.	332-8570	273.000	P.O. BOX 649 Lawai, HI. 96765	halekua@aloha.net
2-7-001-005-0000	Hawaiian Mahogany Inc.	332-8570	244.974	P.O. BOX 649 Lawai, HI. 96765	halekua@aloha.net
2-7-002-001-0000	Hawaiian Mahogany Inc.	332-8570	1162.378	P.O. BOX 649 Lawai, HI. 96765	halekua@aloha.net
2-8-001-003-0000	Hawaiian Mahogany Inc.	332-8570	82.250	P.O. BOX 649 Lawai, HI. 96765	halekua@aloha.net
2-9-002-001-0000	Hawaiian Mahogany Inc.	332-8570	311.950	P.O. BOX 649 Lawai, HI. 96765	halekua@aloha.net
3-4-001-001-0000	Hawaiian Mahogany Inc.	332-8570	316.440	P.O. BOX 649 Lawai, HI. 96765	halekua@aloha.net
3-4-006-001-0000	Hawaiian Mahogany Inc.	332-8570	147.440	P.O. BOX 649 Lawai, HI. 96765	halekua@aloha.net
4-4-002-118-0002	Jane Sezak	822-7508	2.372	P.O. BOX 1555 Kapaa, HI. 96746	jsezak@hotmail.com
4-6-009-035-0001	David Rovinsky	822-2076	1.100	P.O. BOX 1808 Lihue, HI. 96766	
4-6-033-029-0000	Fred Peel	822-4488	2.490	1740 A Mauna Ikena Road Kapaa, HI. 96746	
4-9-009-009-0008	Donald Olson		9.162	47466 San Clemente Terrace Freemont,CA. 94539	
5-1-005-004-0000	Joyce Doty	828-0179	138.862	P.O. BOX 582 Kilauea, HI. 96754	
5-1-005-006-0000	Joyce Doty	828-0179	2.330	P.O. BOX 582 Kilauea, HI. 96754	
5-1-005-022-0000	Joyce Doty	828-0179	30.340	P.O. BOX 582 Kilauea, HI. 96754	
5-1-005-102-0000	Joyce Doty	828-0179	4.430	P.O. BOX 582 Kilauea, HI. 96754	
5-1-005-109-0000	Robert Schaefer	822-1151	2.262	P.O. BOX 3151 Lihue, HI. 96766	
5-1-005-110-0000	Joyce Doty.	828-0179	6.200	P.O. BOX 582 Kilauea, HI. 96754	
5-1-005-111-0000	Joyce Doty	828-0179	6.874	P.O. BOX 582 Kilauea, HI. 96754	
5-1-006-020-0002	Eugene Taylor	828-0191	3.308	4471 D Kapuna Road Kilauea, HI. 96754	
5-1-006-023-0003	John & Claudia Niemiec	828-6893	1.268	4333 Kapuna Road Kilauea, HI. 96754	
5-2-002-011-0003	Neal Norman	828-6488	16.827	52151 Kuhio Hwy. 3 Hanalei, HI. 96714	
5-2-012-019-0001	David Steinmann	212-860-4825	6.500	1185 Park Avenue Apt. 4H New York,NY 10128 1309	
5-2-012-019-0005	Adam Dunsby	203-268-7962	6.830	65 Redding Road Easton CT. 06612	adunsby@ctchost.com
5-2-022-019-0004	Constantin Samoilov	652-0442	4.233	P.O. BOX 824 Chattaroy, WA. 99033	
5-3-008-019-0001	Charlie Bass	826-1951	4.541	3788 Ahonui Place Princeville, HI. 96722	
5-3-008-019-0002	Charlie Bass	826-1951	4.002	3788 Ahonui Place Princeville, HI. 96722	
5-3-008-019-0003	Charlie Bass	826-1951	4.029	3788 Ahonui Place Princeville, HI. 96722	
5-3-008-019-0004	Charlie Bass	826-1951	6.093	3788 Ahonui Place Princeville, HI. 96722	
5-3-008-019-0005	Charlie Bass	826-1951	5.156	3788 Ahonui Place Princeville, HI. 96722	
5-3-008-022-0001	James Gair	702-286-0200	4.495	P.O. BOX 663 Kilauea, HI. 96754	
5-3-008-022-0002	Roy Chambers	826-7115	2.854	P.O. Box 1631 Hanalei, HI. 96714	
5-3-008-022-0003	Robert Isom	828-2036	2.332	P.O. BOX 223201Princeville HI. 96722	
5-3-008-022-0004	Wendy Devore	826-1507	3.867	4170 Kalani Place Princeville, HI. 96722	
5-3-008-022-0005	Greg Fassett	949-464-9989	5.254	1244 N Coast Hwy. Laguna Beach CA.. 92651	gfassett@onlinecsi.com

Potential Timber Resources

Island of Maui

Property Owner	Property Name	TMK Number	Acres	Species	Cubic Foot Volume/ac	Accessibility	Product A	Product B
Maui Land and & Pineapple Co.	Field 16 mauka	2-4-3-01:017	41	*Araucaria* sp.		Bad		
Maui Land and & Pineapple Co.	Field 14 mauka	2-4-3-01:071	46	*Cryptomeria japonica* *Juniperis bermudiana*		Moderate		
Maui Land and & Pineapple Co.	Fields 12/10 mauka	2-4-4-04:008	104	*Cryptomeria japonica* *Juniperis bermudiana*		Moderate		
State of Hawaii	Fields 12/10 mauka	2-4-4-04:010	37	*Cryptomeria japonica* *Juniperis bermudiana* *Eucalyptus* sp.		Good		
State of Hawaii	WMFR/Haelaau	2-4-4-07:006	62	*Araucaria* sp. *Cryptomeria japonica*		Bad		
State of Hawaii	WMFR/Poelua	2-3-1-06:001	72	*Pinus* sp.		Bad		
Ulupalakua Ranch		2-2-2-09:001	160	*Eucalyptus* sp.		Bad		
State of Hawaii	Kula FR	2-2-2-07:001	1942	*Pinus* sp.		Bad		
Thompson Ranch	Waiohuli	2-2-2-04:033 2-2-2-50:052	200	*Eucalyptus* sp.		Bad		
Haleakala Ranch	Puu Pahu/Mountain pastures	2-2-3-05:004	222	*Eucalyptus globulus*		Very Bad		
Haleakala Ranch	Waikamoi	2-2-3-05:004	357	*Pinus* sp.		Bad		
Haleakala Ranch (The Nature Conservancy)	Waikamoi Preserve	2-2-3-05:004	309	*Pinus* sp.		Bad		

Appendix E

Species Descriptions

Saligna Eucalyptus

Myrtaceae -- Myrtle family

Roger G. Skolmen

Saligna eucalyptus *(Eucalyptus saligna),* also called Sydney bluegum, is a fast growing tree, valuable in plantation forestry. It grows in several warm temperate to subtropical countries, such as Brazil and the Republic of South Africa, and the state of Hawaii.

The name *Eucalyptus saligna* was given to type specimens in 1797. Another very similar but distinct species, found within the same geographic range, *Eucalyptus grandis,* was not named until 1918 (12). Before 1918, many introductions were made worldwide of seed collected from "E. *saligna"* that bore the characteristics of the type later to be called *E. grandis.* In most countries where introductions were made, therefore, considerable mixed planting and hybridization of the two species are present. Thus, in Hawaii, most saligna eucalyptus stands contain trees with a range of characteristics intermediate between those of *E. saligna* and *E. grandis. Eucalyptus grandis is* now preferred in South Africa because it self-prunes more readily and has smaller branches (28); and in Brazil because it is resistant to a canker disease and can be propagated vegetatively (6). *Eucalyptus saligna* has grown well where the climate is cooler; for example, in northern New Zealand (12) and in the uplands of Hawaii. Recent provenance tests of the two species in Hawaii suggest that *E. grandis* would be a better choice than *E. saligna* for most sites (26).

Habitat

Native Range

Saligna eucalyptus is native to the east coast of Australia from Bateman's Bay (lat. 36° S.) in southern New South Wales to the southeastern corner of Queensland (lat. 27° S.) (13). In the United States, it has been introduced into Florida, California, and Hawaii. In Hawaii it reproduces at the edges of planted stands. Although it was introduced into Hawaii in the late 1800's, the tree was not planted extensively until the 1960's, when it became the principal tree used for forestation.

Climate

In Australia, the tree grows from sea level to 300 In (1,000 ft) in the South and to 1220 m (4,000 ft) in the North. The climate within this range is warm-temperate to subtropical, with winter frosts to -15° C (5° F) at the higher elevations (12). In New Zealand, seedlings were frost tolerant to a minimum temperature of -7° C (21° F) (21). Rainfall is evenly distributed, or has a summer maximum, and ranges from 890 to 1270 mm (35 to 50 in) annually (13).

In Hawaii, saligna eucalyptus grows well between elevations of about 150 m (500 ft) and 1100 m (3,600 ft) where the temperature is never below 4° C (40° F). One stand is at 1980 m (6,500 ft) where light winter frosts occasionally occur, and the average daytime temperature is about 16° C (60° F). Most of the saligna eucalyptus stands have been planted between 300 and 610 m (1,000 and 2,000 ft) elevation in locations with evenly distributed or winter maximum rainfall of 1520 to 7620 mm (60 to 300 in) annually. The tree achieves its best growth on sites with about 2540 mm (100 in) annual rainfall, rather than on wetter sites, possibly because sunlight is greatly reduced by the cloud cover on wetter sites.

Soils and Topography

In the northern part of its range in Australia, saligna eucalyptus extends to the slopes and ridges. In northern New South Wales and Queensland, it is usually on the slopes, while the closely related rosegum eucalyptus *(Eucalyptus grandis) is* usually near or at the valley bottoms. Saligna eucalyptus does best on clay loams derived from shales and requires good drainage (13).

In Hawaii, saligna eucalyptus has been planted extensively on Histosols and Inceptisols on the island of Hawaii, and also on the Oxisols and Ultisols of Maui, Molokai, Oahu, and Kauai. These soils have in common moderate to strong acidity, low to very low available nitrogen and phosphorus, and rapid to very rapid drainage. All are formed on basaltic parent material, either volcanic ash or rock. In other respects they differ considerably, but all are unsuited or only marginally suited for agriculture. Slopes are usually 10 to 20 percent.

Associated Forest Cover

In Australia, saligna eucalyptus is usually found in mixture with tallowwood eucalyptus *(Eucalyptus microcorys)* and blackbutt eucalyptus *(E. pilularis),* the main coastal species of New South Wales, and is also found associated with several other eucalypts. It seldom grows in pure stands, whereas the closely related rosegum eucalyptus is typically found in pure stands (13). The common names used follow those of Bryan and Walker (2).

In Hawaii, saligna eucalyptus has been planted in mixture with three species of eucalyptus-tallowwood, robusta *(Eucalyptus robusta),* and rosegum-with melaleuca *(Melaleuca quinquenervia),* Formosa koa *(Acacia confusa),* horsetail casuarina *(Casuarina equisetifolia),* silk-oak *(Grevillea robusta),* and a host of other species. On most sites, it has outgrown and shaded out or badly suppressed all of these species except the equally fast growing rosegum eucalyptus and the tolerant Formosa koa. In closed stands, about the only understory species found are strawberry guava *(Psidium cattleianum)* and occasional treefern *(Cibotium spp.).*

Life History

Reproduction and Early Growth

Saligna eucalyptus grown in Hawaii regenerates naturally on bare soil immediately after logging, or on cultivated land adjacent to planted stands. It rarely becomes established in undisturbed grass or brush cover and never in its own shade. Coppicing of stumps is variable. Usually about half to two-thirds of the stumps will sprout (26). Age, weather, and (probably) heredity influence coppicing. The tree also usually produces a mass of special bud tissue at the groundline known as a lignotuber. The lignotuber will sprout if the stem is killed back by fire or other injury.

Flowering and Fruiting- Saligna eucalyptus trees begin to flower at 3 to 4 years of age. Flowering in Hawaii is most prolific during January to March but occurs to some extent year round. In Australia, the tree also flowers from January to March; in California, from April to June. Flowers that consist of numerous stamen filaments surrounding a single shorter pistil occur in umbels of 4 to 9 flowers. Before opening, the flower buds are about 10 mm (0.4 in) long and 5 min (0.2 in) in diameter with a short stalk (pedicel), and a blunt, rather pointed cap (operculum) enclosing the stamens. Flowers are perfect. The opened flowers are yellowish white and are insect pollinated. Pollen is generally shed before the style becomes receptive, so selfing is rare.

The fruit is a dark-brown, bell-shaped capsule 0.8 em (0.3 in) long and 0.5 cm (0.2 in) in diameter. It is short stalked and has four pointed, rim level, or slightly exserted valves. The capsule ripens about 6 months after flowering but opens to release seed 1 or 2 months after ripening (12,13,20).

Seed Production and Dissemination- Seeds are black, irregularly shaped, and about 1.3 min (0.05 in) in diameter. They are released along with a large amount of reddish-brown chaff when the capsule valves open. There are 460 viable seeds per gram (13,000/oz) of seed plus chaff (20).

Seeds are naturally dispersed by wind. They can be collected from ripe capsules dried to open after picking. Some unopened ripe capsules are always present on trees in Hawaii but are most common in August and September. Fresh seeds germinate readily in 10 to 20 days without pregermination treatment. Seeds can be stored in airtight containers for several years at 0° to 5° C (32° to 41° F) (20).

Seedling Development- The seedling has obcordate (inverse heart-shaped) cotyledons that are home epigeously as in all eucalypts. Juvenile leaves are opposite for 3 or 4 pairs, then become alternate, short stalked and lanceolate, and 2.5 by 5.0 cm (1 by 2 in) in size. The adult leaves are alternate, stalked and lanceolate, tapering to a long point, 2.3 by 15 cm (1 by 6 in) in size (13).

In Hawaii, nursery-grown seedlings in containers reach plantable size in 4 to 5 months. Although seedlings are hardy and will survive bare or open-rooted planting, planting of container-grown stock provides more assurance of success if the weather is dry just after planting. Under adverse conditions newly planted seedlings often desiccate and suffer leaf-drop, but such plants usually sprout from the lower stem and recover. When this dieback slows growth, additional weeding or maintenance usually is required to clear competition (32).

Around the world, seeds usually are germinated in flats containing light-textured medium, and seedlings are transplanted into other containers after 6 to 8 weeks when a third pair of leaves begins to appear (12). Seeds also are sown directly into beds or tubes, but thinning of seedlings is usually required with this method because the small seeds are difficult to handle individually. Thinning requirements can be overcome by using pelletized seed and seeding devices (15,31).

In Hawaii, saligna eucalyptus seedlings have been grown extensively in open beds. Because of their rapid growth, these seedlings usually are root pruned at 15-cm (6-in) depth at 6 months and top pruned at 8 months to a 30-cm (12-in) height. Bare root stock frequently has not survived well after field planting, and Hawaii's practice has now changed to growing seedlings only in polyethylene tubes (30).

On favorable sites in Hawaii, planted seedlings grow to about 3 m (10 ft) in height in 1 year, and 3 to 5 in (10 to 16 ft) per year for the next 10 years. After clear cutting of a 44-year-old saligna eucalyptus plantation, natural seedlings that became established grew to saplings that averaged 9 cm (3.5 in) in d.b.h., and 11 rn (36 ft) in height, 22 months after logging. Several of these saplings *were* 18 m (59 ft) tall.

Vegetative Reproduction- Saligna eucalyptus can sprout prolifically from dormant buds located in the cambium throughout the stem. After a tree is cut, shoots sprout from many points on the remaining bark surface. Those highest on the stump suppress those lower down and, if not broken off by wind or by weak attachment, become coppice stems that overgrow the stump (12).

Sprouts will also grow from the lignotuber, a mass of bud tissue at or just below the groundline. Lignotubers are found on saligna eucalyptus from all but its northernmost provenances, but not on rosegum eucalyptus (12). In managing saligna eucalyptus for coppice, it is desirable to cut stumps 12 cm (5 in) or less in height, so that the sprouts will develop from near the lignotuber. Such sprouts generally are more firmly attached but are frequently suppressed by sprouts arising from higher on the stump. Lignotubers persist when stems are killed by shading, thinning, or fire and often sprout vigorously after a mature stand is cut (8).

Rooting of cuttings of saligna eucalyptus had been difficult (16) until a method was developed at the Aracruz Co. in Brazil (7). The method consists of collecting coppice sprouts that are just beginning to harden and keeping them constantly moist while 2-leaf-pair cuttings are prepared and end-dipped in rooting hormone. The cuttings are placed under intermittent mist in individual containers. In Hawaii, saligna eucalyptus has been easier to root than *E. grandis,* although most success elsewhere has been with *E. grandis* (3,7). However, just as was found for *E. grandis* in Brazil (6), cutting rootability is variable among coppice from individual saligna eucalyptus trees.

Tissue culture propagation has also been successful in Hawaii. The techniques used with saligna eucalyptus are essentially those reported by Boulay (1) for other eucalyptus species. Terminal and lateral shoot tips of greenhouse-grown rooted cuttings are multiplied, separated, and rooted in sterile culture, and afterwards grown *to* normal *size* in a mist chamber. A number of propagules of saligna eucalyptus produced by tissue culture are now being compared in clonal progeny tests.

Grafting success has been reported for saligna eucalyptus (24,27). Cleft, side, splice, and bottle grafting were all used successfully, but the tests were not observed for a long enough period to determine the extent of long-term incompatibility, a problem with many species of *Eucalyptus.*

Sapling and Pole Stages to Maturity

Growth and Yield- Saligna eucalyptus is a fast growing tree, well suited for producing high yields of wood fiber on short rotations. Measurements of a plantation spacing study on a good site at Kaumahina, Maui (29) provide an example. Four spacings were tested: 2.4 by 2.4 m, 3.0 by 3.0 in, 3.7 by 3.7 m, and 4.3 by 4.3 m (8, 10, 12, and 14 ft). At 2 years, trees averaged 9.6 cm (3.8 in) in d.b.h. and 10.7 rn (35 ft) in height. At 5 years, they had grown to 20.8 cm (8.2 in) in d.b.h. and 22.9 in (75 ft). Mean annual volume increment had already peaked at the two closer spacings in the study and was rapidly leveling out at the wider spacings. At 15 years, the trees in this study averaged 26.7 cm (10.5 in) in d.b.h. and 39 in (129 ft) tall. The largest tree was 61 cm (24 in) in d.b.h. and 49 rn (161 ft) tall. At 5 years, the trees at 2.4 by 2.4 m (8 by 8 ft) had produced 294 m³/ha (4,200 ft³/acre), or 58.8 m³/ha (840 ft³/acre) per year. At 15 years, these trees yielded 683 m³/ha (9,759 ft³/acre), or 45.6 m³/ha (651 ft³/acre) per year. Trees at 4.3 by 4.3 m (14 by 14 ft) yielded 33.1 m³/ha (473 ft³/acre) per year.

These figures are comparable to those of *Eucalyptus grandis/E. saligna* grown in other countries. In Kenya, a mean annual increment over 5-year periods of 21 m³/ha (300 ft³/acre) for the seedling crop followed by 32 m³/ha (457 ft³/acre) for the first coppice crop was obtained (11). Other mean annual increment figures cited for *E. grandis* are 14 to 45 m³/ha (200 to 643 ft³/acre) in Uganda, 28 m³/ha (400 ft³/acre) in Zambia, 50 m³/ha (715 ft³/acre) at 14 years in Argentina, and 22 m³/ha (314 ft³/acre) in New South Wales, the native habitat of both species (12).

In two 4-year-old stands in Hawaii, annual increment averaged 13 and 36 m^3/ha (185 and 515 ft^3/acre). The faster growing stand yielded wood with a specific gravity of 0.41 for an estimated annual dry-weight yield of stem wood of 15 tonnes/ha (6.7 tons/acre).

The tallest tree in Hawaii, thought to be the tallest hardwood in the United States, is a saligna eucalyptus. When last measured in 1979, the tree was about 50 years old, 137 cm. (54 in) in d.b.h. and 82.3 m (270 ft) tall.

Rooting Habit- Saligna eucalyptus develops roots throughout the soil profile so that it is quite windfirm on deep soils, but easily windthrown on shallow soils. It does not produce a taproot. Roots are primarily from the stem below the lignotuber, although layering sometimes occurs a short distance from the lignotuber on buried stems. In plantations in Hawaii that are not subject to periodic short drought, about two-thirds of the root system is confined to the upper 61 cm (24 in) of soil where most of the available nutrients are found. In plantations subject to occasional drying of the surface soil, the shallow roots are killed and a deeper root system develops.

Reaction to Competition- Because the tree is such a fast starter, planted seedlings can frequently grow faster than surrounding grass and herbaceous vegetation and shade it out. This is particularly true if the seedlings have an intact root system when planted, as in modern tube container planting, so that little or no "shock" occurs to delay new growth after planting. At the upper elevational boundaries of sugarcane fields, saligna eucalyptus grown from seed in the soil at the time of cane harvest actually outgrew the sugarcane ratoon crop.

In Hawaii, original plantings are made on completely cleared land. Pre-emergent herbicides, though effective, have rarely been used. If pre-emergents are not used, one cleaning around trees that require it is made after 3 months and, depending on the site, a second cleaning may sometimes be made at 6 months. Further weeding is seldom necessary. Coppice growth of saligna eucalyptus is so rapid that competing plants are rarely a problem after cutting.

Tests in Hawaii show that the leguminous tree *Albizia falcataria* outgrows saligna eucalyptus on some sites when planted row on row with both species equally fertilized. It is one of the few woody plants known that can grow this fast on sites that are suited for saligna eucalyptus. The trials of mixing the legume with E. saligna produced increased yields of the eucalypt on some wet sites, but reduced yields on other, drier sites (10).

In South Africa, thinning schedules have been developed for trees planted at 1330/ha (538/acre) that call for thinning 25 percent of the stems present at 6 years when the stems removed are 13 cm (5 in) in diameter, and 25 percent again at 10 years when they are 20 cm (8 in) (12). These thinnings are continued at 3- to 5-year intervals until a sawtimber harvest is made at age 30. In the interim, all stumps are allowed to coppice to keep the site free of competition and to supply fuelwood crops.

Saligna eucalyptus is classed as very intolerant of shade and the slower growing trees in a stand quickly become suppressed. In Hawaii, crown closure is usually complete and crown differentiation begins in 3 years in stands planted at 3 by 3 in (10 by 10 ft). In coppice stands where numerous stems grow from every stump, crown differentiation begins as soon as sprouts appear. Many studies have shown that the maximum yield of wood is obtained by not thinning coppice at all (12). However, if larger diameter and straighter stems are desired, thinning to one to three stems per stump is desirable.

Damaging Agents- Saligna eucalyptus grown in plantations in many parts of the world is susceptible to the eucalyptus canker disease, *Cryphonectria cubensis.* The disease kills young trees, deforms stems, and causes basal cankers that reduce the coppicing ability of stumps (19). Rosegum eucalyptus is somewhat resistant and *Eucalyptus urophylla,* perhaps, is immune to the disease, so these species are now being used in place of *E. saligna* in many Brazilian plantings. In Hawaii, the disease is present only on the island of Kauai. It attacks *E. grandis* in Florida but is not causing serious damage (18).

In Western Australia, two other canker diseases, *Botryosphaeria ribis* and *Endothia havaensis,* were determined to be pathogenic on *E. saligna* planted there, while another, *Cytospora eucalypticola,* was present but less damaging (14).

Phoracantha semipunctata, a wood-boring insect, degrades wood and reduces growth of eucalyptus in many places, including Hawaii, but is only a serious problem in trees that are stressed by severe drought. In Australia, saligna eucalyptus is subject to damage by *Spondyliaspis* psyllids, which predispose the trees to attack by the wood-boring beetle *Xyleborus truncatus* (22).

In Hawaii, wind damage is a severe problem. In January 1980, a severe windstorm caused severe blowdown in 75 percent of the saligna eucalyptus stands planted during the 1960's (17).

Special Uses

In Hawaii, saligna eucalyptus has been used to some extent for sawtimber, but only with considerable difficulty and expense. Most of the milling and lumber quality problems are those associated with growth stress-severe end-splitting of logs, spring of cants during sawing, compression failures, and brashness of the wood near the pith (25). Because of this, the tree is now planted primarily for early harvest as pulpwood, or, if it proves economic in the near future, as industrial fuelwood to replace oil.

Elsewhere in the world, particularly in South Africa and Brazil, the trees and their close relative, *E. grandis,* are grown extensively for pulp, poles, and fuel.

Genetics

Population Differences

In an attempt to solve the problem of confused and probably mixed introductions of *Eucalyptus saligna* and *E. grandis,* differences between them have been noted for mature trees in South Africa (12), as follows:

E. saligna	***E. grandis***
Bark: smooth type bluish; rough type on lower stem	Bark: smooth type white; rough type often extends up stem
Flowering (South Africa): January to April	Flowering (South Africa); July to December
Valves of fruit: 3 or 4 pointed, straight or spreading	Valves of fruit: 4 to 6 blunt, incurved
Root crown: Lignotuberous	Root crown: Not lignotuberous
Branches: Persistent under shade	Not persistent under shade

These characteristics vary among provenances of each species. The northernmost provenances of saligna eucalyptus, for example, do not have lignotubers (12). When grown in some locations, for example, Hawaii, flowering seasons overlap and trees probably hybridize extensively. Among 6-year-old trees of provenances collected in Australia growing side-by-side at two locations in Hawaii, no consistent differences were observed between *E. saligna* and *E. grandis* in leaves, bark, or branching habit (26).

Saligna eucalyptus produces denser wood than *E. grandis,* but in Hawaii (26), and also in the Republic of South Africa (9) where yields of the two species growing on the same sites have been compared, the best performing *E. grandis* provenances for a particular site produce a higher total weight yield than *E. saligna,* despite the wood density difference.

Hybrids

Because of the wide international interest and the problems of hybridization and identification of the two species, a comparison of *E. saligna* and *E. grandis* populations representative of the entire range of each species was made in Australia (4). Distinct differences were found in seedling and mature-tree morphology and allozyme frequencies between core populations of the two, but intermediate types were found in some remote locations. Core mature saligna eucalyptus had smaller seed, upright valves (4 per fruit), and non-glaucous fruit and branchlets as compared with *E. grandis,* which had larger seed, incurved valves in 5's, glaucous fruit and branchlets. Saligna eucalyptus seedlings had lignotubers and were glaucous; not so, *E. grandis.* Saligna eucalyptus seedlings also had smaller cotyledons and narrower, longer leaves. The allozyme patterns found for native populations in Australia showed species differences and were later compared to patterns found for populations collected in the Republic of South Africa, which were thought to be hybridized (5). All the South African trees sampled fell within the allozyme patterns found in Australia for *E. grandis,* even though several were morphologically suspect.

In addition to the *Eucalyptus grandis/E. saligna* complex, *E. saligna* crosses with *E. robusta,* bangalay eucalyptus *(E. botryoides),* and probably with forest redgum eucalyptus *(E. tereticornis) (12,28).* In the southern part of its natural range, a region of introgression of *E. saligna* with *E. botryoides* exists (23).

Robusta Eucalyptus

Myrtaceae -- Myrtle family

James R King and Roger G. Skolmen

Robusta eucalyptus, *Eucalyptus robusta, is* native to a narrow coastal area in southeastern Australia. The species is widely adaptable and has been introduced into many tropical, subtropical, and warm-temperate climates including Puerto Rico, southern Florida, coastal California, and Hawaii. It is naturalized only in southern Florida and Hawaii. Commonly called swamp-mahogany in Australia, it is usually called robusta eucalyptus in the United States (2,16), and beakpod eucalyptus in Puerto Rico (17).

The species was originally introduced as a candidate for timber production, fuel, watershed protection, and windbreaks. By 1960, more than 4650 ha (11,500 acres) of plantations were established in Hawaii. The species has been studied in Florida as a source of pulpwood (8).

Habitat

Range and Climate

Robusta eucalyptus is native along the Australian coast of New South Wales and southeast Queensland. It is found mainly in swamps and on the edges of coastal lagoons and rivers where it is subject to periodic flooding (5,9). The mean maximum temperature in the hottest month is 30° to 32° C (86° to 90° F); the mean minimum of the coldest month is about 3° to 5° C (37° to 41° F). Throughout the native range, from 5 to 10 light frosts occur each year (6).

In Hawaii, robusta eucalyptus grows well from near sea level to 1100 m (3,600 ft) where annual rainfall ranges from 1000 mm (40 in) to 6350 mm (250 in) and temperatures rarely if ever reach freezing.

Robusta eucalyptus in Florida grows mainly in the southern portion of the State where frosts may occur annually. Mean annual rainfall averages 1320 min (52 in) with 70 to 80 percent of rain falling during the May to October wet season.

In Puerto Rico the species makes its best growth in mountain regions about 460 m (1,500 ft) where annual rainfall averages 2540 mm (100 in) (17).

In southern California and along coastal northern California, plantings of robusta eucalyptus have been subject to several unseasonal cold spells (11,20,21) where temperatures reached -9° C (16° F). In every instance severe foliage damage was initially observed (more than 80 percent of the crown foliage killed), but the stems recovered within 3 months.

Although robusta eucalyptus can recover from occasional severe frost damage, the limiting variable in its distribution seems to be low temperature. If the temperature drops below -9° C (16° F) annually, introduced robusta eucalyptus will seldom be successful. In Yunnan Province, China, -7° C (19° F) damaged robusta eucalyptus, but to a lesser extent than *E. globulus (4).*

Soils and Topography

Robusta eucalyptus grows well on a variety of soils, ranging from its native intermittently flooded sites (6,9) to the hot summer-dry soils of California's Central Valley (11).

In Florida, typical soils are poorly drained, acid, fine sands with hardpans at depths proportional to the depth of the seasonally high water table. Robusta eucalyptus does best on the least poorly drained of these soils, which are typical of arenic and aeric haplaquods of the order Spodosols (7).

Most robusta eucalyptus in Hawaii are planted on sites considered too steep for agriculture-usually slopes of 10 to 20 percent. On the older islands of Kauai, Oahu, Molokai, and Maui, trees were planted predominantly on Oxisols and Ultisols. On the youngest island, Hawaii, plantings are mainly on Histosols and Inceptisols. All these soils are formed on basaltic parent materials, either volcanic ash or lava rocks. Soils are low in nitrogen and phosphorus and often strongly acidic. The lava substrate may be in either almost continuous sheets or in highly fractured porous clinkers. Soil drainage, therefore, varies from very poor to extremely rapid in very short distances.

Associated Forest Cover

In its native range the species is dominant in some areas and is often found in pure stands. Associated trees may include kinogum eucalyptus *(Eucalyptus resinifera),* bloodwood eucalyptus *(E. gummifera),* forest redgum eucalyptus *(E. tereticornis),* longleaf casuarina *(Casuarina glauca),* and various species of *Melaleuca (8).*

Throughout the 1930's, when most of the tree planting was done in Hawaii, robusta eucalyptus was used to overplant failed plantations. Consequently, because robusta eucalyptus could survive on a wide variety of sites, it is found in many mixed plantings. Some common associates with robusta eucalyptus are saligna eucalyptus *(Eucalyptus saligna),* tallowwood eucalyptus (E. *microcorys),* melaleuca *(Melaleuca quinquenervia),* horsetail casuarina *(Casuarina equisetifolia),* and silk-oak *(Grevilla robusta).* Treefern *(Cibotium spp.)* is also quite common in the understory of planted stands. One report refers to a pure stand of robusta eucalyptus being heavily invaded by Javanese podocarpus *(Podocarpus cupressina).* On wetter- sites on the island of Hawaii, robusta eucalyptus stands often develop a dense, almost impenetrable, understory of strawberry guava *(Psidium cattleianum).*

Life History

Reproduction and Early Growth

Flowering and Fruiting- Robusta eucalyptus has perfect flowers that are insect pollinated. In Florida, California, and Hawaii, trees have been observed to flower by the end of the third growing season. The peak flowering season in Florida is from September to November (7), and the peak season in California is from January to March (11). In Hawaii and more tropical areas, new flowers may appear at almost any time of the year and individual trees occasionally bloom year-round.

The trees flower with 5 to 10 flowered axillary umbels. The sepals and petals are fused into a caplike structure (operculum) that drops off the tip of the flower bud at anthesis. The eucalypts are, in general, protandrous (23). The showy part of the cream-colored flower is actually the numerous filamentous stamens that surround the stigma.

The fruit is a vase-shaped dark green capsule 12 to 15 mm (0.5 to 0.6 in) long that contains many small seeds. The fruit ripens 5 to 7 months after flowering.

Seed Production and Dissemination- Seeds of robusta eucalyptus are small and like all eucalyptus contain no endosperm. The viable seed is difficult to separate from the chaff (unfertilized or aborted ovules) in the ripe flower capsules. There are 200 to 400 viable seeds per gram (5,700 to 11,300/oz) of seed and chaff (12).

Seed dispersal is largely by wind and may begin within 6 weeks after the seed capsule ripens. In Florida, most trees retain seeds in closed capsules for more than 1 year after ripening (7).

Seedling Development- Germination is epigeal (12). Robusta eucalyptus in Florida has occasionally reproduced naturally around abandoned homesteads, probably following fire on the native range. The seed source was usually an old amenity planting of robusta eucalyptus and the seedlings outgrew the disturbed native vegetation. The species does not invade recently abandoned agricultural fields because of the more intense competition from weeds (7).

Most robusta eucalyptus stands in Florida are being established through the planting of container-grown stock. Seedlings in Florida need several months to grow into frost-hardy saplings before facing their first frost. Early spring planting would be ideal, but soil moisture is deficient until summer rainfall begins. Thus mid-June through mid-August is the recommended planting period (7).

Most robusta eucalyptus stands in Hawaii have been established as single species plantings and, after logging or other disturbance, regenerate as pure stands of coppice and seedlings. Robusta eucalyptus has recently been used in biomass plantations. These were all made with container-grown

seedlings to assure the rapid early start needed to stay ahead of the wide variety of competing, aggressive vegetation (25). After planting, container-grown seedlings in Hawaii grow almost 30 cm (12 in) per month for the first few years.

Vegetative Reproduction- The majority of new stems in logged stands of robusta eucalyptus are of coppice origin. These coppice shoots arise from dormant buds in the cambium of the stump. All parts of the stem surface under the bark contain dormant buds that sprout rapidly after crown injury.

Robusta eucalyptus is one of the *Eucalyptus* species that produces lignotubers. A lignotuber consists of a mass of vegetative buds and contains substantial food reserves. It begins forming in the axils of the cotyledons and the first three pairs of the seedling leaves. Eventually these organs are overgrown by the main stem and remain as tuberous bulges just above the root crown.

When robusta eucalyptus is logged, therefore, the source of the coppice is usually the dormant buds in the stem cambium surrounding the stump. But if the entire stem is killed through fire, or in young seedlings through grazing, new coppice shoots may arise from the lignotubers (23). In a Florida test, robusta eucalyptus coppicing proved to be less influenced by season of cutting than either *E. grandis* or a hybrid *E. grandis x robusta,* but was reduced during the hot, dry summer (26).

No rooted cuttings of robusta eucalyptus have been used on a commercial scale, but cuttings taken from young seedlings and young coppice shoots have been successfully rooted (10).

Sapling and Pole Stages to Maturity

Growth and Yield- In 1960, a study in eight different Hawaiian plantations of robusta eucalyptus gave the following growth data for plantations at elevations ranging from 395 to 730 m (1,300 to 2,400 ft), and trees aged 23 to 38 years, with 358 to 642 trees per hectare (145 to 260/acre) larger than 28 cm (11 in) in d.b.h. (14,22):

Basal area: 51 to 184 m^2/ha (220 to 800 ft^2/acre).
Height of dominants: 28 to 55 m (93 to 179 ft).
Mean annual growth per stand: 7 to 48 m^3/ha (100 to 685 ft^3/acre).
Mean annual growth for all eight stands: 26 m^3/ha (370 ft^3/acre).

One of Florida's first eucalyptus plantations of operational scale established with genetically improved seedlings was established in 1972 on a palmetto prairie site. Within this planting, a system of inventory plots was established to develop the data needed to determine optimum rotation length, expected yields, and other management guidelines. Although the planting is considered seriously understocked with 786 trees per hectare (318 trees/acre), measurements at 10.25 years estimate a mean annual yield of 16.7 m^3/ha (238 ft^3/acre). Mean height of all stems was 16.6 m (54.5 ft) and height of dominant class trees only was 21.3 m (70 ft). Stand volume in 1979 was 172 m^3/ha (2,458 ft^3/acre) (7,18).

Planted trees in Puerto Rico have reached 27.4 m (90 ft) in height and 41 cm (16 in) in d.b.h. in 15 years (17). Coppice stands often outproduce seedling stands. A 10-year-old coppice stand in Hawaii produced 140 m^3/ha (2,000 ft^3/acre), while an adjacent 12-year-old seedling stand yielded only 96 m^3 /ha (1,372 ft^3/acre) (3).

Rooting Habit- The most distinctive characteristic of the rooting habit of robusta eucalyptus in Hawaii is the tree's ability, in moist areas, to initiate adventitious roots from buds on the stem at heights of 6 to 12 m (20 to 40 ft) (fig. 2) (13). These roots grow downward through the moist bark and into the soil. As the root grows in diameter, it sometimes breaks free from the soft bark and appears as an aerial root. The lower stems of occasional robusta eucalyptus become completely encased in an interwoven mass of these aerial roots, some of them 20 cm (8 in) in diameter (14). The species rarely displays this habit in its native range or in more temperate climates. Adventitious roots, however, have been noted on a robusta eucalyptus in the Sydney Botanical Garden in Australia, and near Rio de Janeiro (15). Although some layering from the stem may occur as noted earlier, most roots originate below the lignotubers and occupy the entire available soil profile on well-drained sites. Robusta eucalyptus is usually quite windfirm on deeper soils and is often used for windbreaks in Hawaii.

Reaction to Competition- Robusta eucalyptus is classed as intolerant of shade. Where planted in alternate rows with saligna eucalyptus it is invariably overtopped, suppressed, and usually dies within 30 years. In Hawaii, robusta eucalyptus is planted on prepared sites and usually grows faster than weedy competitors invading the site. On extremely refractory sites robusta eucalyptus is considered the species of last resort because of its remarkable ability to survive and grow.

Damaging Agents-Robusta eucalyptus is remarkably free of serious insects or diseases when grown in the United States. *Cylindrocladium scoparium* has caused serious losses of seedlings in Florida (1). However, this fungus can now be successfully controlled by fumigation of soil and containers with methyl bromide before sowing and a followup treatment with benomyl spray. The major cause of damage to robusta eucalyptus stands in Hawaii is wind (14). Violent windstorms have snapped stems and uprooted trees. Uprooting damage can be particularly severe when stands are established in shallow soils overlaying a solid mantle of lava rock. Naturally, such shallow soils should be avoided and planting concentrated on soils or fractured bedrock where roots can penetrate to greater depths.

In Florida, robusta eucalyptus plantings at about age 5 may develop a condition called "robusta breakup." Patches of young trees may develop a bend in the main stem or on primary branches. Breakage may also occur along the main stem or primary branches, and the wood at the point of breakage may appear dry and brash. No primary pathogens or pests have been associated with this breakage. Minor element deficiencies are suspected but are not proven as the cause. Adjacent stands of rosegum eucalyptus *(Eucalyptus grandis)* appear unaffected (7).

Special Uses

Robusta eucalyptus has found use in urban forestry and as farm windbreaks because of its dark shiny leaves and its generally dense crown. Twigs and branches continually die off and fall to the ground, however, so that the tree is rather hazardous for use in parklands, campgrounds, or even gardens. On the island of Kauai, an older roadside planting of robusta eucalyptus, though most attractive, is maintained at a high cost for road cleanup.

Genetics

Population Differences

We know of no published data on population differences in robusta eucalyptus. Studies (see "Races") using seed collections from Australia could be suitable for grouping and analyzing by particular provenances, but such analyses have not been reported.

Races

In 1975, foresters in southern Florida established a genetic base population of 352 collections of *Eucalyptus robusta* from individual selected trees in Australia, advanced generation families from two previous generations of selection in Florida, as well as selections from Florida's naturalized stands. This base population was subsequently selected and rogued to form a seedling seed orchard that produces seeds of a *bona fide* land race of *E. robusta* for southern Florida. This seed orchard was also a source of genetic material for an effort to develop *E. grandis* and *E. robusta* hybrids adapted to Florida conditions (7,19).

Hybrids

Several natural hybrids involving *Eucalyptus robusta* have been reported (24). All of the known interspecific hybrids are between *E. robusta* and other species of the subgenus *Symphomyrtus.* Several have been assigned recognized botanical names. They are *E. botryoides* var. *platycarpa (E. botryoides x robusta), E. grandis* var. *grandiflora (E. grandis x robusta), E. longifolia* var. *multiflora (E. longifolia x robusta), E. kirtoniana (E. robusta x tereticornis), E. patentinervis, E. insizwaensis (E. robusta x globulus,* probably), and an unnamed hybrid (E. *robusta x saligna,* probably).

ELEMENT STEWARDSHIP ABSTRACT
for

Fraxinu uhdei

Tropical Ash

The Nature Conservancy
Element Stewardship Abstract
For Fraxinus uhdei

I. IDENTIFIERS

Common Name: Global Rank: G?

General Description:
Tree of the olive family (Oleacea) reaching up to 25 m tall.

Pest/Weed Considerations:
Found on major islands; pest on Oahu and Malokai (Smith 1985). considered a pest on Oahu and Molokai (Smith 1985). considered a pest on Oahu and Molokai (Smith 1985).

II. STEWARDSHIP SUMMARY

Fraxinus uhdei is a habitat-disruptive alien plant species in Hawaii, at least on Molokai and Oahu. Its success as a weed is due to prolific seedling recruitment, rapid early growth, and the shade tolerance of seedlings and saplings. Manual and mechanical methods can be used for smaller plants, although their efficiency is problematic. Ring notching or cut stump with Garlon 3A is recommended for larger plants. Control efforts should begin with outlying plants and the edges of larger stands and progress toward the center of the stands. Monitoring the recovery of highly altered stands following control efforts is warranted. Control efforts should begin immediately at Kamakou Preserve, but can be prioritized below other species at Waikamoi Preserve. Detailed studies of life-history and ecology are not needed, although seed viability in the soil is of interest to management.

III. NATURAL HISTORY

Range:
Native to western and southern Mexico, it was introduced to Hawaii originally as a shade tree.

Habitat:
Fraxinus uhdei was planted extensively starting in the 1920's as a watershed species, and in the 1960's as a potential timber species. Over 700,000 trees were planted, all apparently from the same seed source, two trees on Oahu planted in the 1890's (Little and Skolmen 1989).

Fraxinus uhdei appears to have a rather broad range of tolerance. It has been planted and escaped from plantings in wet and mesic environments. It grows best between 1,000 and 1,700 m elevation but also up to 2,000 m (Smith 1985). Nelson and Schubert (1976) report that it grows best from 450-1500 m in moist, well-drained sites. In mesic and dry areas, it is usually confined to gulches and wet areas (Skolmen, pers. comm., 1991).

Reproduction:
Fraxinus uhdei regenerates mostly or possibly exclusively from seed (Skolmen, pers. comm., 1991). Seed production is copious. Although fruits are apparently adapted for wind-dispersal, establishments appear to be rather short range, suggesting that wind dispersal infrequent. Seeds banks may survive up to eight years, as suggested by continued seedling recruitment in populations controlled at Hawaii Volcanoes National Park. Its success as an invading species is probably due to copious seed production, ability to regenerate under its own canopy, shade tolerance of young plants, and rapid growth of seedlings, saplings, and poles.

Impacts:
Smith (1985) considers Fraxinus uhdei to be one of the 86 alien plant species most disruptive to native ecosystems in Hawaii because it can form single species stands. It appears to be more of a threat at Kamakou Preserve than Waikamoi. Its dispersal at Kamakou is enhanced by strategic location of the numerous plantings. Ash can be spread down stream and down slope from plantings. Tropical ash is slowly expanding uphill at Waikamoi. Recruitment from the seed bank appears to be considerably less than that in Kamakou.

IV. CONDITION

V. MANAGEMENT/MONITORING

Preserve Selection & Design Considerations:
The recovery of sites from which Fraxinus uhdei has been removed has not been determined to date. Recommended control programs at Kamakou will test recovery potential.

Management Requirements:
Control of Fraxinus uhdei should be a high priority at Kamakou Preserve. Tropical ash has altered fairly extensive areas, especially species-rich drainages. Small plantings and natural outliers are numerous, suggesting that tropical ash may spread rapidly in the future. Control efforts are not urgent at Waikamoi Preserve where stands are smaller, less altered, and opportunities for dispersal reduced.

Only seedlings and small saplings can be uprooted manually. A weed wrench may be effective on larger saplings, but relatively time-consuming. Use of an herbicide is required for larger plants. Arakaki et al. (1989) found that undiluted Garlon 3A in a continuous ring notch application offered complete control. Use of Garlon 3A as a cut stump applications should be more practical for smaller trees. Lower concentrations than that recommended for notching may also be effective. Management should start with outlying populations and the edges of larger stands and work toward the center of the stand.

Management Programs:
Some control, especially of smaller plants, has been undertaken at Kamamkou. Four small populations were controlled at Hawaii Volcanoes National Park, although control efforts are still needed on seedlings.

Monitoring Requirements:
Monitoring is needed at Kamakou Preserve to determine the complete distribution of Fraxinus uhdei in the preserve, management effectiveness once control efforts begin, and recovery of stands in which it is controlled.

Distribution mapping and quantitative assessments of cover and density in treated stands.

Monitoring Programs:
Houck (1987) used releves to characterize vegetation in Fraxinus uhdei stands. Their utility for monitoring depends on the ability of future investigators to relocate these unmarked study sites.

VI. RESEARCH

Management Research Programs:
Houck (1987) attempted to document the impact of Fraxinus uhdei on native vegetation by characterizing tropical ash dominated stands in Kamakou Preserve. Arakaki et al. 1989 found an effective herbicide to control tropical ash. No other published literature could be located on conservation management aspects of this species. Most of the limited research literature deals with experimental forestry planting of tropical ash in Hawaii.

Management Research Needs:
Houck's report (Houch 1987) is useful in elucidating its interaction with native vegetation and indicating the magnitude of the threat posed by Fraxinus uhdei to Kamakou Preserve. (Unfortunately, few studies of this kind have been conducted for disruptive alien plant species in Hawaii.) The monitoring described above should be sufficient for management purposes.

In general, thorough studies of life-history and ecology are warranted for widely spread disruptive species such as strawberry guava (Psidium cattleianum) and clidemia (Clidemia hirta). However, testing viability of tropical ash seed under field conditions will help managers in developing control programs. This can be done by burying seed in soil in containers below the level at which light stimulated germination will take place. A sample can be extracted every 6-12 months, and seeds can be tested for germination under greenhouse or laboratory conditions.

VII. ADDITIONAL TOPICS

VIII. INFORMATION SOURCES

Bibliography:

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Smith, C. W. 1985. Impact of alien plants on Hawaii's native biota. pp. 180-250. in C. P. Stone and J. M. Scott (eds.). Hawaii's terrestrial ecosystems: preservation and management. Univ. Hawaii Coop. Natl. Park Resour. Studies Unit, University of Hawaii Press. 584 pp.

IX. DOCUMENT PREPARATION & MAINTENANCE

Edition Date: 1991-08-12

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Toona Ciliata Australian Red Cedar Toon

Family: MELIACEAE

Synonym: *Toona australis* (F. Muell.) Harms., *Cedrela australis* F. Muell., *Cedrela toona* Roxb var. *australis* C. DC.

Derivation: *Toona* from *Toon* the Indian name for the tree; *australis* from Latin *australis* southern.

Common Name: Red Cedar.

Standard Trade Name: Red Cedar (RCD).

Habit: A large ***deciduous*** tree generally with a wide spreading and handsome crown attaining a height of 45 m and a stem diameter of 210 cm.

Trunk: Buttressed, flanged or fairly cylindrical.

Bark: Reddish brown, glossy when young, when older changes to brown or grey, scaly, shed in oblong or irregular pieces, leaving slight depressions in the surface of the bark. Typical Red Cedar fragrance.

Branchlets: Thick, brown or ***red*** on the leafy section, smooth or minutely downy with a few cream raised lenticels. Leaf scars distinct, ***young shoots finely downy***.

Leaves: Alternate, ***pinnate***, consisting of ***five to seventeen leaflets***. Leaflets opposite or irregularly alternate, ovate-lanceolate, 4-13 cm long, often drawn out to a long point at the tip, unequal at the base. Green both surfaces, paler beneath, ***red and downy when young***. Primary leaf stalk 3-9 cm to the first leaflets. Leaflet stalks 3-6 mm long.

Venation: Visible on both surfaces but more prominent on the underside. Sometimes reddish or purplish in colour, ***occasionally*** there are ***tufts of hairs*** where the lateral veins join the midrib.

Flowers: White, fragrant, in a large pyramidal panicle at the ends of the branchlets. Individual flowers about 5 mm long. Flowering period September to November.

Fruit: A ***dry capsule, light brown***, elliptical, about 18 mm long, ***splitting into five valves containing four to five winged seeds*** about 13-18 mm long in each valve. Fruit ripe January to March.

Habitat: Subtropical to riverine rainforests but also on alluvial soils in warm temperate rainforest. Formerly most plentiful on the basaltic-derived alluvial flats of larger rivers.

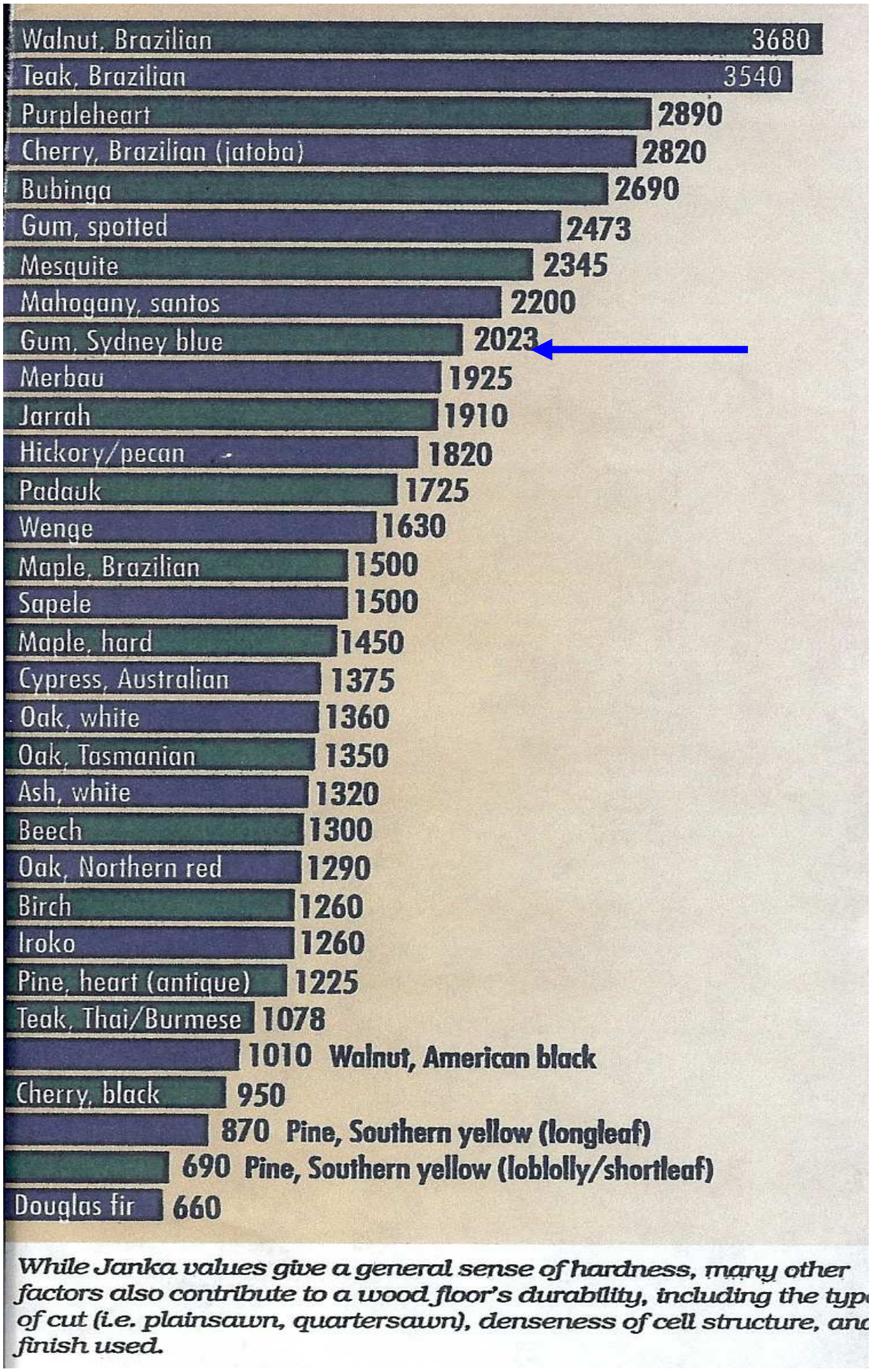
Distribution: Coastal rainforests from Benandarah, NSW to McIllwraith Range, North Queensland.

Timber and uses: Red, soft, light and durable. Probably the most favoured and valued Australian timber for furniture and cabinet work and interior decoration. Lyctid borer susceptible. Density 450 kg/m^3.

Regeneration: 200 000-300 000 seeds per kilogram. Germination of fresh sown seed is very rapid, commencing within 7 days and complete with 68% germination after 28 days. Can be stored at -4ºC for 5 years with 97% germination and even after 121 years with 38% germination. The first three seedling leaves are three-lobed with a larger terminal toothed lobe. Fourth to seventh leaves are trifoliate, while the eighth to tenth are five foliate. All leaves up to sixteen are toothed, but subsequent leaves are entire.

Field Identification Characters: Deciduous tree; bark and timber distinctively 'cedar'; young shoots red and finely downy; leaves alternate, pinnate, 5-17 leaflets; fruit a dry capsule, light brown, splitting into five valves; seeds winged.

Relative Hardness of Woods



Source: National Hardwood Floor Association

Appendix G
Acknowledgements

Last Name	First Name		Company or affiliation
Bello	**Eric**	**Mr.**	**HIH and Bello's Millwork**
Brauner	**Hal**	**Mr.**	**Brauner Moulding and Millwork**
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HFIA			**Web site data**
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